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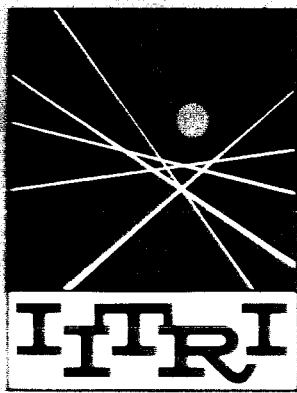
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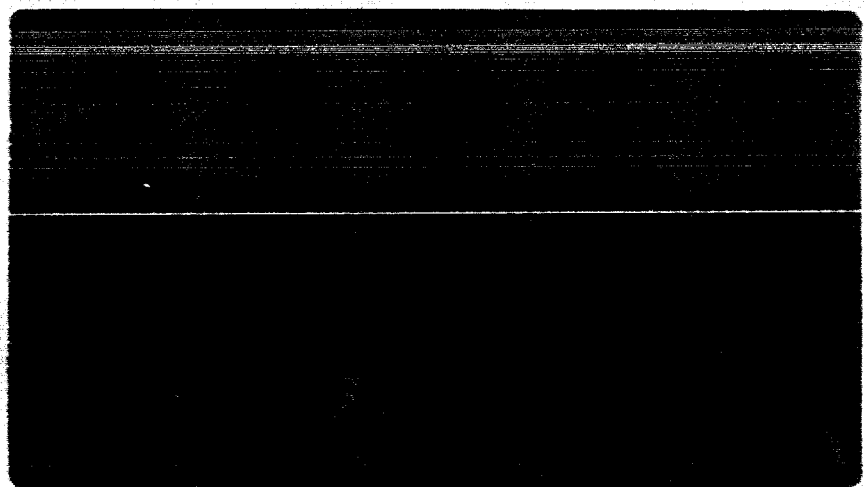
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Phase Report No. 1,
IITRI Project No. M6053
EXPERIMENTAL DETERMINATION OF STRESS
DISTRIBUTIONS IN THIN WALLED CYLINDRICAL
AND SPHERICAL PRESSURE VESSELS
WITH CIRCULAR NOZZLES

by

W. F. Riley

7 Mar. 1962 -
1 Nov. 1963
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IIT RESEARCH INSTITUTE
Technology Center
Chicago 16, Illinois

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EXPERIMENTAL DETERMINATION OF STRESS DISTRIBUTIONS
IN THIN WALLED CYLINDRICAL AND SPHERICAL
PRESSURE VESSELS WITH CIRCULAR NOZZLES

Prepared by
W. F. Riley

for

Subcommittee on Reinforced Openings
Pressure Vessel Research Committee

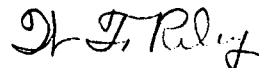
December 11, 1963

This is the first phase report on IIT Research Institute (IITRI) Project No. M6053 which is being conducted for the Pressure Vessel Research Committee (PVRC) to determine stress distributions in thin walled cylindrical and spherical pressure vessels with circular nozzles. The period covered by this report extends from March 7, 1962 to November 1, 1963. At the beginning of the program approximately 8 months were required to procure the experimental models. The report thus covers the experimental studies which were conducted during a one year period from 1 November 1962 to 1 November 1963.

Research Institute personnel who made significant contributions to the program include: J. P. Cistaro, J. W. Dally, T. M. Kroll, E. M. Naureckas, T. Niiro and W. F. Riley.

Respectfully submitted,

IIT RESEARCH INSTITUTE



W. F. Riley, Manager
Experimental Stress Analysis Section

WFR:lc

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EXPERIMENTAL DETERMINATION OF STRESS DISTRIBUTIONS
IN THIN WALLED CYLINDRICAL AND SPHERICAL
PRESSURE VESSELS WITH CIRCULAR NOZZLES

ABSTRACT

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This report contains the complete results of a study which was conducted to determine stress distributions in thin walled cylindrical and spherical pressure vessels with nozzles. During the period covered by the report studies were conducted on a cylindrical vessel ($D/t = 240$) with a circular nozzle ($d/D = 0.5$) and on a spherical vessel ($D/t = 240$) with a circular nozzle ($d/D = 0.5$). Stress distributions were determined in each vessel for internal pressure, axial thrust on the nozzle, and external moment forms of loading. The results are presented in both graphical and tabular form.

Author

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EXPERIMENTAL DETERMINATION OF STRESS DISTRIBUTIONS IN THIN WALLED CYLINDRICAL AND SPHERICAL PRESSURE VESSELS WITH CIRCULAR NOZZLES

I. INTRODUCTION

For a number of years the Pressure Vessel Research Committee of the Welding Research Council has been concerned with the problem of stress distributions in the vicinity of openings in various types of pressure vessels. Studies which have been conducted to obtain stress distributions for internal pressure and external moment and thrust loadings have included:

- a) Theoretical analyses
- b) Three-dimensional photoelasticity studies, and
- c) Electrical resistance strain gage studies on steel models.

This report deals with an electrical resistance strain gage study which was conducted to determine stress distributions in very thin cylindrical and spherical vessels with non-reinforced circular nozzles.

In the following sections of the report a complete description is given of the two models used to date in the program, the instrumentation techniques, and the methods of loading. Complete results for the studies are presented in both graphical and tabular form.

II. MODEL DESCRIPTION

The models used for the study include a cylindrical vessel ($D/t = 240$) with a circular nozzle ($d/D = 0.5$) and a spherical vessel ($D/t = 240$) with a circular nozzle ($d/D = 0.5$). The essential features of each are shown in Figs. 1 and 2 respectively.

Both vessels were fabricated by Graver Tank and Manufacturing Company from hot rolled 12 gauge sheet steel. As a result the thickness of the vessels is relatively uniform. The thickness of the cylindrical vessel was determined to be 0.104 ± 0.002 in. The thickness of the

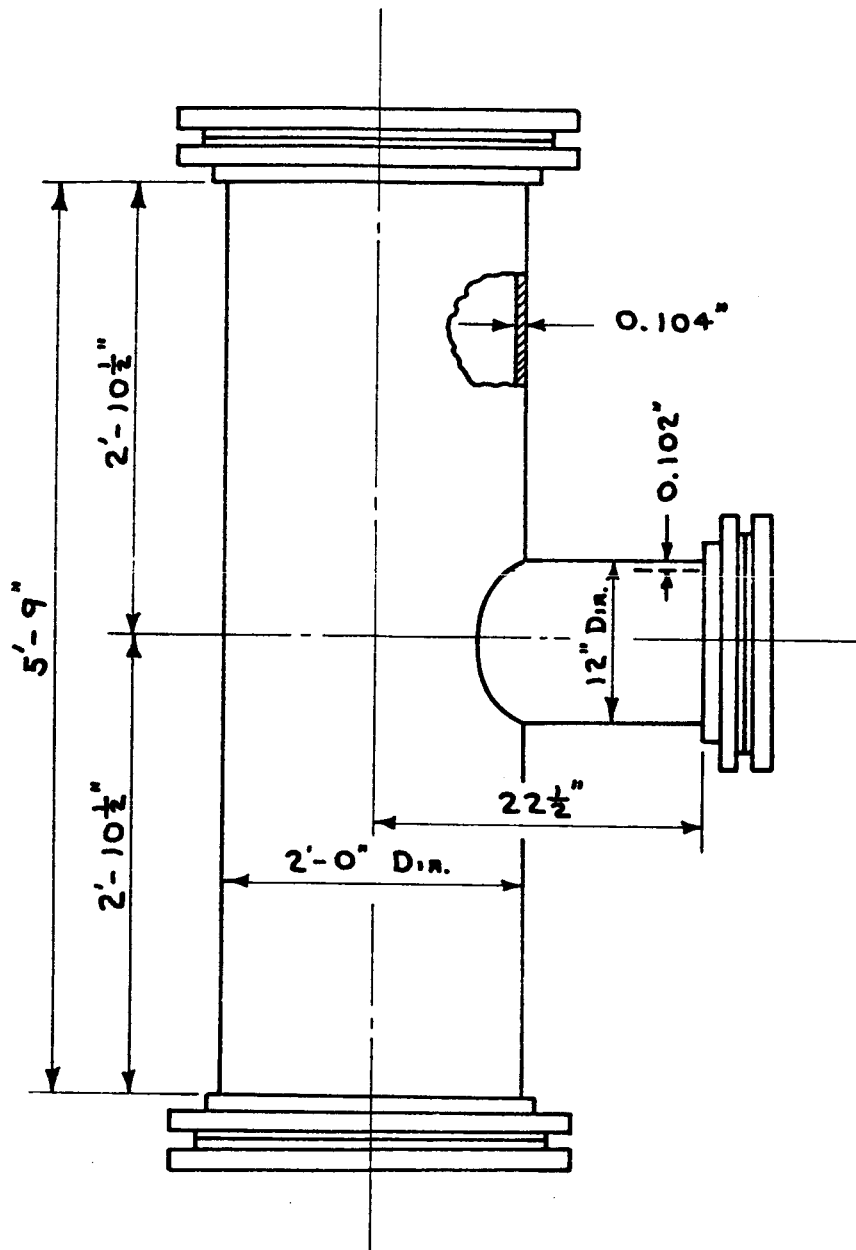


Fig. 1 SKETCH SHOWING THE ESSENTIAL FEATURES OF
THE CYLINDRICAL MODEL (VESSEL C-1)

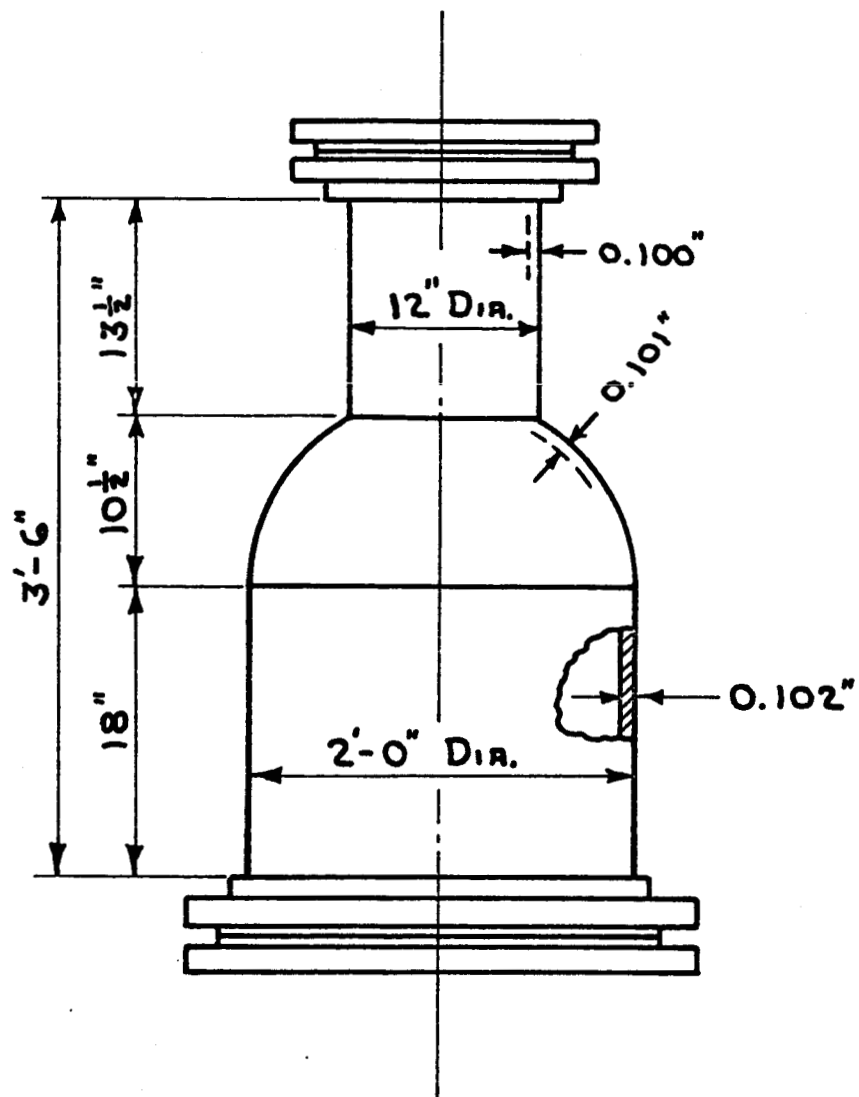


Fig. 2 SKETCH SHOWING THE ESSENTIAL FEATURES OF
THE SPHERICAL MODEL (VESSEL S-1)

nozzle of the cylindrical vessel was determined to be 0.102 ± 0.001 in. The vessel was fabricated with a single longitudinal butt weld in both the cylinder and the nozzle. The nozzle was inserted essentially flush with the inside surface of the cylinder and approximately $1/4$ " of weld material was introduced to form the fillet between the nozzle and cylinder. On the inside surface of the vessel a bead of weld was introduced to insure complete penetration.

The hemispherical head which was used for the spherical vessel was obtained from Spincraft in Milwaukee. Measurements of thickness on the head as received indicated variations from 0.086 to 0.109 in. The thin section was located from the base to approximately the 45° location on the hemisphere. The thick section was located in the region of the opening introduced for the nozzle. A 2 inch region in the vicinity of the nozzle was reduced to 0.101 ± 0.001 in. before the nozzle was inserted. The nozzle thickness was determined to be 0.100 ± 0.001 in. The welding procedure used for this vessel was the same as that previously described for the cylindrical vessel.

After the vessels were delivered to IITRI the inside and outside fillets were hand finished with templates. The radii are estimated to range from $1/8$ to $5/32$ in. It should be noted here that the outside radius was formed completely in weld material. The inside radius was also partially formed in weld material.

The out-of-roundness of the vessels were established with a series of diameter measurements. The results are shown in Tables 1-3.

III. MODEL INSTRUMENTATION

The cylindrical model was instrumented along the transverse line of symmetry, along the longitudinal line of symmetry and at selected locations in the fillet between the cylinder and the nozzle. On the two lines of symmetry gages were installed in both the hoop and axial directions on both the interior and exterior surfaces. The lines of principal interest are referred to as primary lines. Partial instrumentation was also installed on a secondary line 180° from the primary line. Gages were applied at similar locations on the spherical model.

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Table 1
DIAMETER MEASUREMENTS ON THE NOZZLE OF VESSEL C-1

Distance From Nozzle Flange** (inches)	Diameter (inches) Angular Position*			
	0°	45°	90°	135°
1.0	11.844	11.930	11.960	11.990
3.0	11.867	11.925	11.960	11.962
5.0	11.894	11.917	11.948	11.940
7.0	11.914	11.921	-	11.932
9.0	11.917	11.921	-	11.938
11.0	11.919	11.902	-	11.929

* Measured with respect to the transverse axis.

** On the longitudinal axis the flange is 10-1/2" from the cylinder.

Table 2
DIAMETER MEASUREMENTS ON THE CYLINDER OF VESSEL C-1

Distance From End Flange** (inches)	Diameter (inches) Angular Position*			
	0°	45°	90°	135°
1	24.038	23.981	24.027	23.997
10	23.999	23.968	24.057	24.033
19	23.946	23.985	24.062	24.050
22	23.931	23.994	24.064	24.045
25	23.940	24.000	24.064	24.028
28	-	24.008	24.063	24.020
31	-	24.002	24.061	24.048
34	-	23.980	24.062	-
35	-	23.996	24.059	-
38	-	23.995	24.060	24.017
41	23.905	23.994	24.059	24.036
44	23.923	23.990	24.059	24.014
47	23.924	23.983	24.058	24.016
50	23.927	23.981	24.056	24.059
59	23.956	23.948	24.046	24.016
68	24.012	23.925	24.045	24.041

* Measured with respect to the plane which contains the centerline of the nozzle and cylinder.

** Centerline of the vessel located at 34-1/2".

Table 3
DIAMETER MEASUREMENTS ON THE NOZZLE OF VESSEL S-1

Distance From Fillet (inches)	Diameter (inches) Angular Position*			
	0°	45°	90°	135°
0.5	-	11.730	12.035	-
2.5	11.844	11.773	12.034	12.048
4.5	11.851	11.809	12.003	12.032
6.5	11.866	11.837	11.996	12.007
8.5	11.886	11.859	11.971	11.992
10.5	11.898	11.884	11.945	11.963
12.5	11.913	11.913	11.952	11.940

* Measured from the line of strain gages.

The locations of the gages on the longitudinal plane of symmetry in the cylindrical model are shown in Fig. 3. Similar locations for the transverse plane of symmetry of the cylindrical model and for the spherical model are shown in Fig. 4. Gage locations in the fillet for both vessels are shown in Fig. 5. At the 0° , 90° , 180° , and 270° locations, gages were installed on both the inside and outside surfaces of the fillets. At the other fillet locations only the exterior fillet was instrumented.

All of the gages used in the study were of the foil type manufactured by the Budd Company. All fillet gages and gages $1/4''$ from the fillet had a gage length of $1/32''$ (C6-1X1-32 or C6-1X1-32B). Gages at locations $3/4''$ from the fillet had $1/16''$ gage lengths (C6-111). All other gages had a $1/8''$ gage length and were of the 2 element rosette type (C6-121-R2B). Suitable switch boxes and a Baldwin Model 20 strain indicator were used for all measurements.

IV. MODEL LOADINGS

The forms of loading applied to the models for the study were as follows:

a) Cylindrical Model

- 1) Internal pressure
- 2) Thrust (directed inward)
- 3) Thrust (directed outward)
- 4) Transverse moment (clockwise*)
- 5) Transverse moment (counterclockwise)
- 6) Longitudinal moment (clockwise)
- 7) Longitudinal moment (counterclockwise)
- 8) Combined internal pressure and transverse moment.

b) Spherical Model

- 1) Internal pressure
- 2) Thrust (directed outward)
- 3) Moment (clockwise)

* A moment has arbitrarily been designated clockwise if it tends to produce tensile axial stresses along the primary line of study.

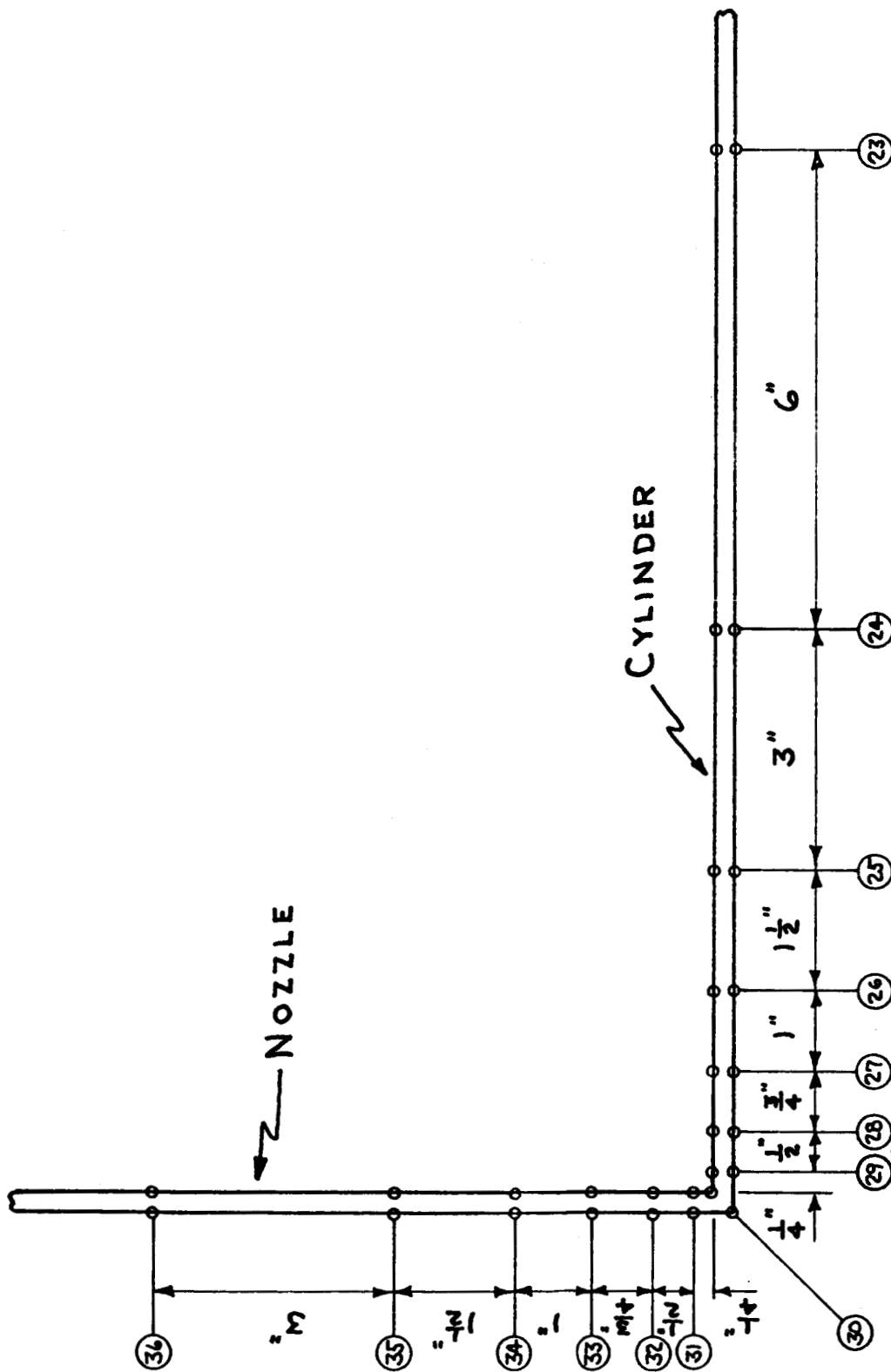


Fig. 3 STRAIN GAGE LOCATIONS ON THE LONGITUDINAL PLANE OF VESSEL C-1

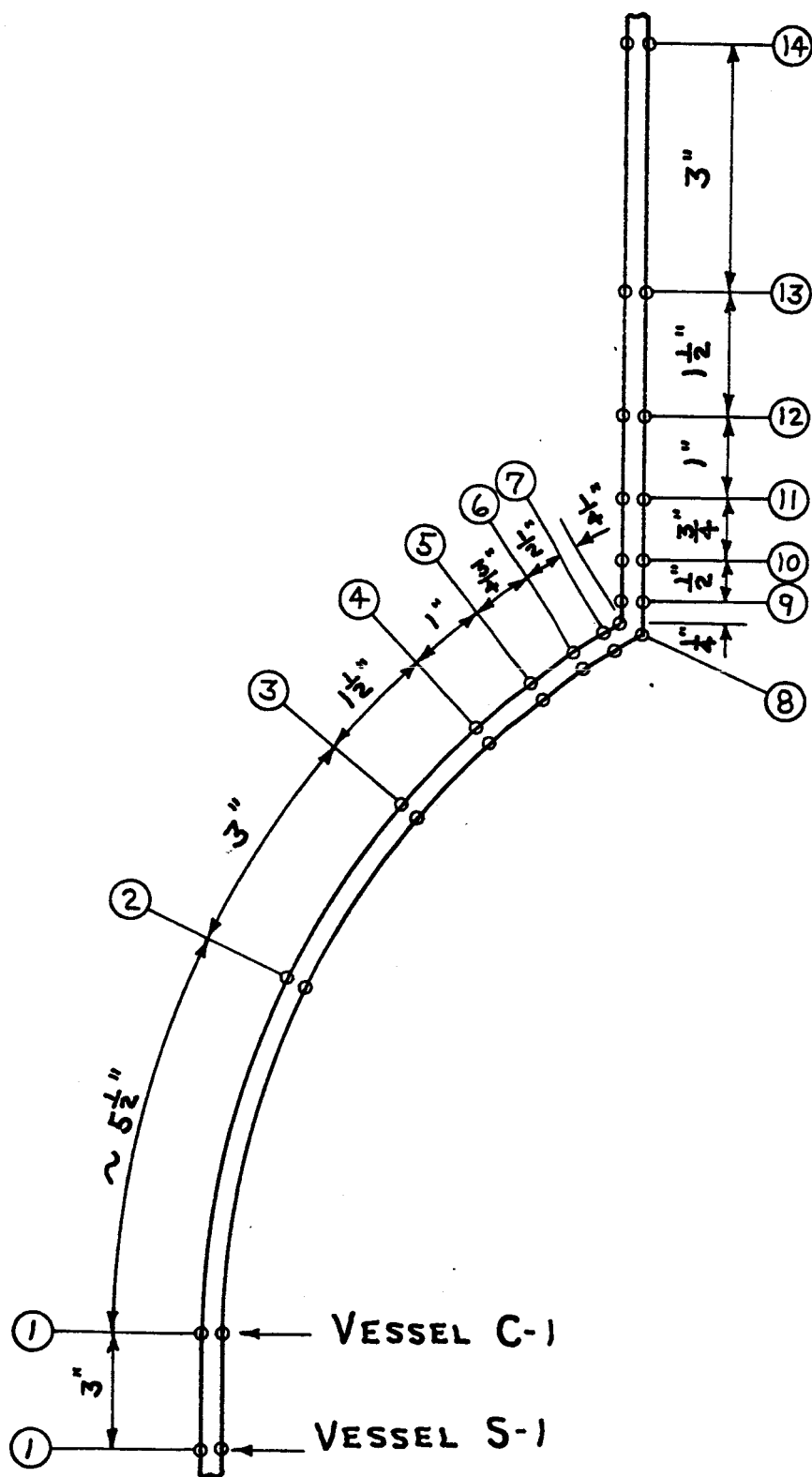


Fig. 4 STRAIN GAGE LOCATIONS ON VESSEL S-1 AND
THE TRANSVERSE PLANE OF VESSEL C-1

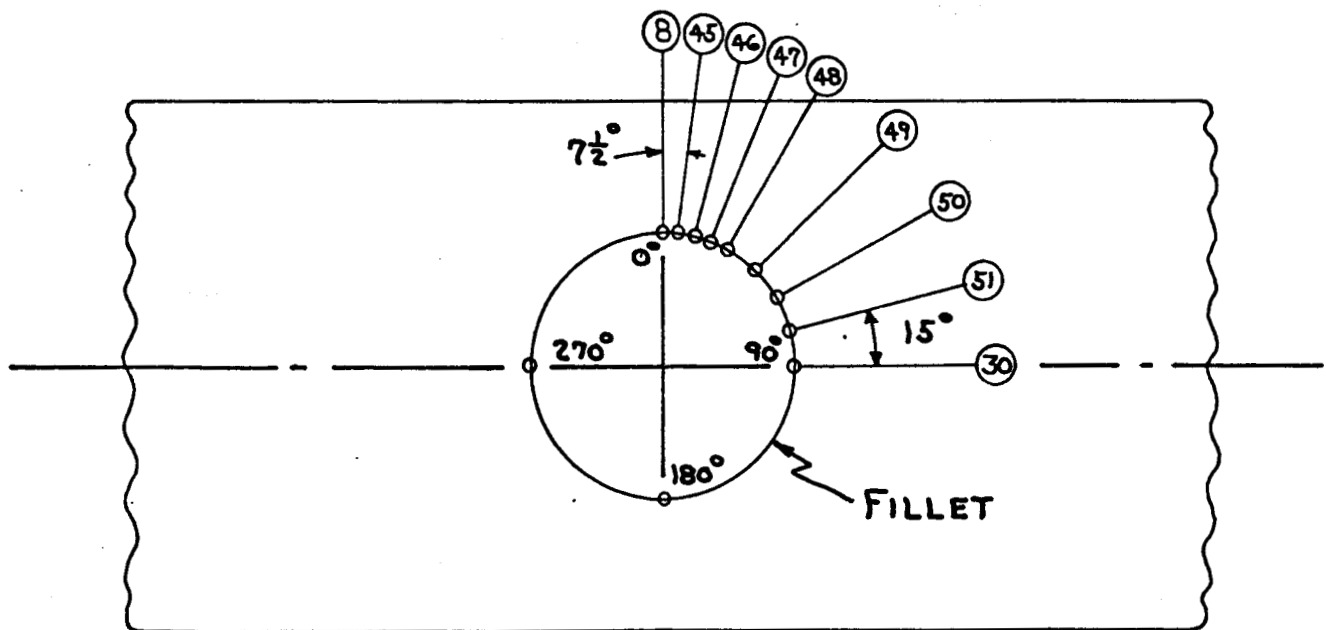
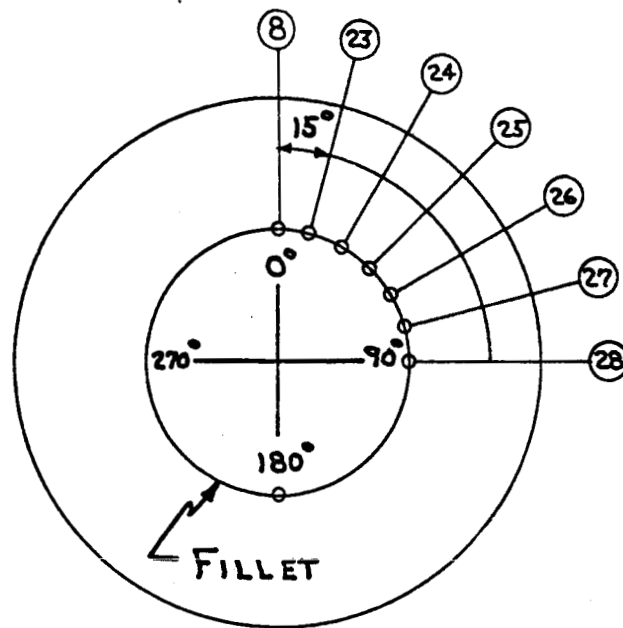


Fig. 5 STRAIN GAGE LOCATIONS IN THE FILLETS OF VESSELS
S-1 AND C-1

The internal pressure loadings were applied to both models with compressed air. A maximum pressure of 30 psi was applied to the cylindrical model. The maximum for the spherical model was 60 psi.

The axial thrust loadings were applied to the models with hydraulic rams. During application of the loads the end flanges of the vessels were restrained by a structural frame. The loads were applied to the nozzle through a 6" I beam approximately 80 inches long which was bolted to the nozzle flange. The hydraulic rams were located between the restraining structure and the beam at the ends of the beam.

Originally it was planned to use the same beam and ram system for applying the bending moments (couples) to the nozzle. The forces required for the moment loadings were small, however, so a system of levers and weights were used in place of the rams. This permitted a more accurate measurement of the applied loads.

V. DATA REDUCTION AND RESULTS

A. Data Reduction

Five strain gage readings were obtained for each gage: an initial zero, readings at 3 different load levels, and a final zero reading. The gages were all wired into the system but were read in blocks of approximately 50 gages. In this way the time between the initial zero reading and the final zero reading was minimized. In most instances the initial and final readings agreed within 10 μ in/in. In cases where the two zero readings differed appreciably the measurements were repeated on a subsequent loading. If the condition persisted the gage was replaced. The strains at the three load levels were then used to establish the strain at a selected load level. This value was then used in all subsequent computations.

B. Results

The results of the study are presented in both tabular and graphical form. The tabulated data is complete. Graphs have been prepared, however, only for the internal pressure, outward thrust, and clockwise moments. The data from the other thrust and moment loadings indicates that the stress distribution is essentially the same with the

sign reversed.

In conducting the tests and reducing the data one difficulty was encountered which remains to be satisfactorily resolved. This involves location and orientation of the gage for the third strain measurement at each of the fillet locations which are away from the axes of symmetry. Since the fillet was finished to a 1/8 in. radius, the strain gage must have a gage length not greater than 1/32 in. Commercial 3 gage rosettes are not available with this gage length so individual gages had to be used. The axial and circumferential gage could be positioned with a reasonable degree of accuracy. The third gage was not satisfactorily positioned as indicated by the extreme scatter in a plot of the data. Thus only the axial and hoop components of the fillet stresses were computed. The two principal stresses remain to be evaluated.

1) Cylindrical Vessel

- a) Internal pressure: Stress magnitudes at all gage locations in the model for a 30 psi internal pressure are presented in Tables 4-6. Stress distributions along the transverse line of study, along the longitudinal line of study, and as a function of angular position in the fillet are plotted in Figs. 6-10. The hoop direction for the fillet is consistent with the hoop direction for the nozzle at the longitudinal and transverse planes of symmetry. For this form of loading the maximum stress appears to occur in the fillet approximately 20° from the transverse plane of symmetry.
- b) Thrust loading on the nozzle: Stress magnitudes at all gage locations in the model for both an outward directed thrust and an inward directed thrust of 1000 lbs are presented in Tables 7-12. Stress distributions along the transverse line of study, along the longitudinal line of study, and as a function of angular position in the fillet are plotted in Figs. 11-15 for the case of an outward directed thrust. A comparison of the data presented in

the tables for the two cases shows satisfactory agreement. For this form of loading the maximum stress occurs in the fillet on the transverse axis of symmetry.

- c. Transverse moment on the nozzle: Stress magnitudes at all gage locations on the transverse plane of symmetry in the model and at the fillet gage locations are presented in Tables 13-16 for both a clockwise and counterclockwise couple of 3000 in-lbs on the nozzle. The stress magnitudes along the longitudinal plane of symmetry at all locations away from the fillet were negligible for this form of loading. Stress distributions for the clockwise moment along the transverse line of interest and as a function of angular position in the fillet are shown in Figs. 16-18. For this form of loading the maximum stress occurs in the fillet on the transverse axis of symmetry.
- d. Longitudinal moment on the nozzle: Stress magnitudes at all gage locations on the longitudinal plane of symmetry in the model and at the fillet gage locations are presented in Tables 17-20 for both a clockwise and a counterclockwise couple of 18000 in-lbs on the nozzle. For this loading the stress magnitudes at gage locations on the transverse plane of symmetry away from the fillet were negligible. Stress distributions for the clockwise moment are shown in Figs. 19-21. For this form of loading the maximum stress occurs in the fillet approximately 30° from the transverse plane of symmetry.
- e. Internal pressure plus transverse moment: In Tables 21 and 22 stress magnitudes are presented for a combined internal pressure (15 psi) and transverse moment (3000 in-lb) form of loading. The data indicates that the stress magnitudes for the various forms of loading can be superimposed to give the stress magnitudes for a combined load.

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2) Spherical Vessel

- a) Internal pressure: In Tables 23 and 24 stress magnitudes are presented at all gage locations for an internal pressure of 60 psi. Stress distributions along the line of study and as a function of angular position in the fillet are plotted in Figs. 22-24. The scatter in Fig. 24 can be attributed to imperfections in the vessel, slight errors in gage orientation and errors in gage location. The data presented in this figure gives an excellent illustration of the variation in stress magnitudes to be expected in studies of this type.
- b) Thrust loading on the nozzle: Stress magnitudes at all gage locations for an outward directed thrust on the nozzle of 6000 lbs are presented in Tables 25 and 26. Stress distributions for the line of study and for the fillet are shown in Figs. 25-27. The scatter in the data in Fig. 27 is of the same order of magnitude as that presented previously in Fig. 24.
- c) Moment loading on the nozzle: Stress magnitudes at all gage locations on the vessel for a clockwise couple of 18000 in-lbs are presented in Tables 27 and 28. Stress distribution along the line of study and around the fillet are plotted in Figs. 28-30. In Fig. 30 some tendency is indicated that the maximum stress occurs in the fillet away from the plane of bending.

Table 4

PRINCIPAL STRESSES ON THE TRANSVERSE PLANE OF VESSEL C-1
FOR AN INTERNAL PRESSURE OF 30 PSI

Gage No.	Gage Location	PRIMARY LINE				SECONDARY LINE			
		Outside		Inside		Outside		Inside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
1	Cylinder	+ 2.0	+ 3.8	+ 1.9	+ 1.5	+ 2.7	+ 4.5	+ 1.8	+ 1.8
2	Cylinder	- 1.9	- 0.5	+ 1.9	+ 6.5	-	-	-	-
3	Cylinder	- 1.4	- 3.4	+ 3.5	+10.0	- 0.6	- 2.7	+ 3.5	+11.0
4	Cylinder	+ 4.3	+ 1.2	+ 3.8	+ 6.0	-	-	-	-
5	Cylinder	+ 9.9	+ 8.1	+ 2.3	- 2.0	+ 9.8	+ 8.6	+ 1.8	- 3.2
6	Cylinder	+11.0	+12.5	+ 0.8	- 7.7	-	-	-	-
7	Cylinder	+10.8	+13.3	- 2.1	-12.5	+10.4	+12.2	- 1.4	-11.9
9	Nozzle	+ 7.8	+ 7.4	- 6.0	+ 2.3	+ 7.0	+ 6.8	- 5.3	+ 3.3
10	Nozzle	- 1.5	+ 3.8	+ 0.6	+ 1.9	-	-	-	-
11	Nozzle	- 1.7	+ 1.8	+ 1.1	+ 1.1	- 1.0	+ 2.1	+ 1.1	+ 0.9
12	Nozzle	- 1.0	+ 1.1	+ 1.1	+ 0.8	-	-	-	-
13	Nozzle	+ 0.4	+ 2.0	+ 0.8	+ 1.1	+ 0.3	+ 1.7	+ 0.5	+ 2.1
14	Nozzle	+ 0.8	+ 2.0	+ 0.7	+ 1.3	-	-	-	-

Table 5

PRINCIPAL STRESSES ON THE LONGITUDINAL PLANE OF VESSEL C-1
FOR AN INTERNAL PRESSURE OF 30 PSI

Gage No.	Gage Location	PRIMARY LINE				SECONDARY LINE			
		Outside		Inside		Outside		Inside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
23	Cylinder	+ 2.4	+ 4.7	+ 1.7	+ 1.8	-	-	-	-
24	Cylinder	+ 2.9	+ 4.3	+ 2.1	+ 2.5	-	-	-	-
25	Cylinder	+ 3.2	+ 3.7	+ 2.1	+ 2.4	+ 3.0	+ 3.6	+ 1.7	+ 1.7
26	Cylinder	+ 2.6	+ 3.0	+ 4.4	+ 3.3	-	-	-	-
27	Cylinder	+ 2.3	+ 3.8	+ 5.9	+ 4.6	+ 2.4	+ 3.3	+ 7.8	+ 6.4
28	Cylinder	+ 3.0	+ 10.9	+ 2.4	+ 9.3	-	-	-	-
29	Cylinder	+ 14.5	+ 18.0	- 10.2	+ 10.7	+ 16.3	+ 20.1	- 12.5	+ 11.3
31	Nozzle	+ 10.5	+ 16.4	- 9.5	+ 10.5	+ 12.3	+ 18.3	- 11.3	+ 9.8
32	Nozzle	- 1.9	+ 5.0	+ 5.5	+ 7.5	-	-	-	-
33	Nozzle	- 1.5	+ 0.9	+ 4.4	+ 1.5	- 1.8	+ 0.8	+ 4.0	+ 1.4
34	Nozzle	+ 1.2	+ 0.9	+ 1.8	+ 1.1	-	-	-	-
35	Nozzle	+ 1.3	+ 1.5	+ 0.8	+ 1.7	+ 1.4	+ 1.1	+ 0.7	+ 1.9
36	Nozzle	+ 0.9	+ 1.7	+ 0.6	+ 1.7	-	-	-	-

Table 6
**FILLET STRESSES IN VESSEL C-1 FOR AN INTERNAL
PRESSURE OF 30 PSI**

Gage No.	Gage Location	FILLET STRESS			
		Outside		Inside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
8	0°	+16.2	+11.8	-7.1	+ 0.8
45	7-1/2°	+18.3	+10.9	-	-
46	15°	+24.3	+11.7	-	-
47	22-1/2°	+28.8	+16.7	-	-
48	30°	+27.8	+15.8	-	-
49	45°	+20.2	+16.2	-	-
50	60°	+16.1	+18.3	-	-
51	75°	+16.3	+19.5	-	-
30	90°	+15.4	+19.4	-3.3	+12.7
19	180°	+14.3	+10.9	-5.9	+ 1.2
41	270°	+15.1	+22.0	-3.0	+14.8

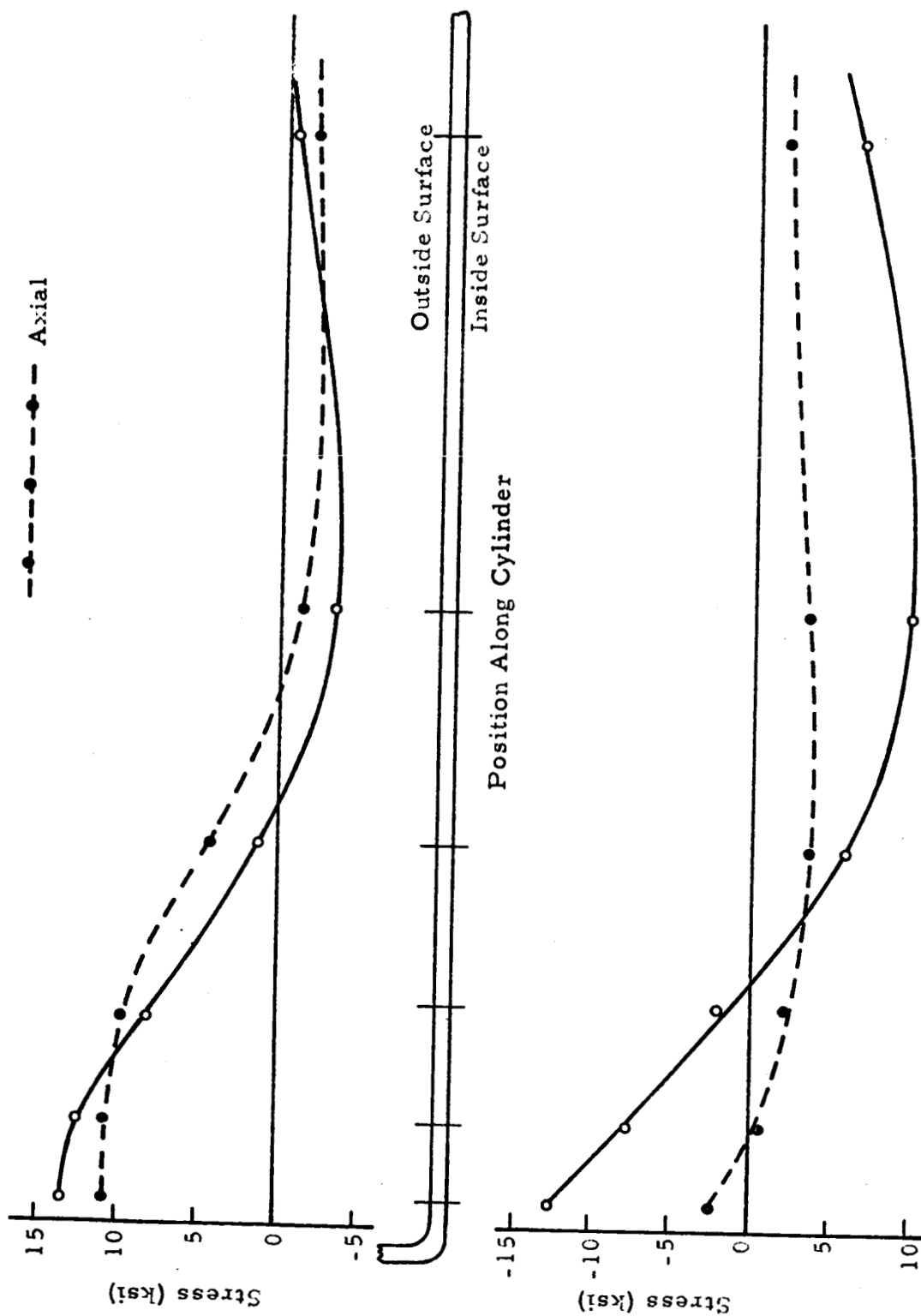


Fig. 6 STRESS DISTRIBUTION ALONG THE TRANSVERSE LINE OF THE CYLINDER FOR AN INTERNAL PRESSURE OF 30 PSI

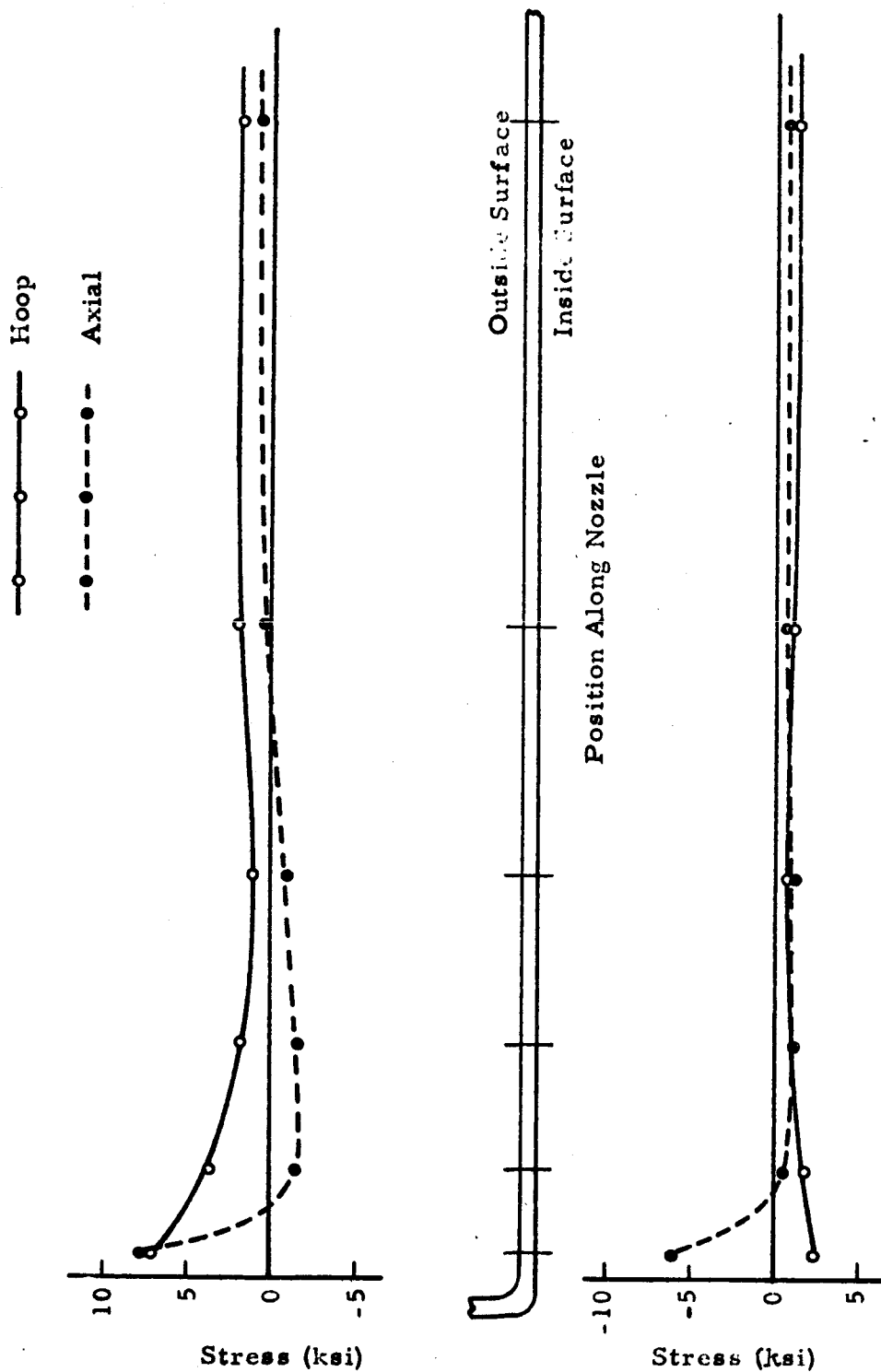


Fig. 7 STRESS DISTRIBUTION ALONG THE TRANSVERSE LINE
OF THE NOZZLE FOR AN INTERNAL PRESSURE OF 30 PSI

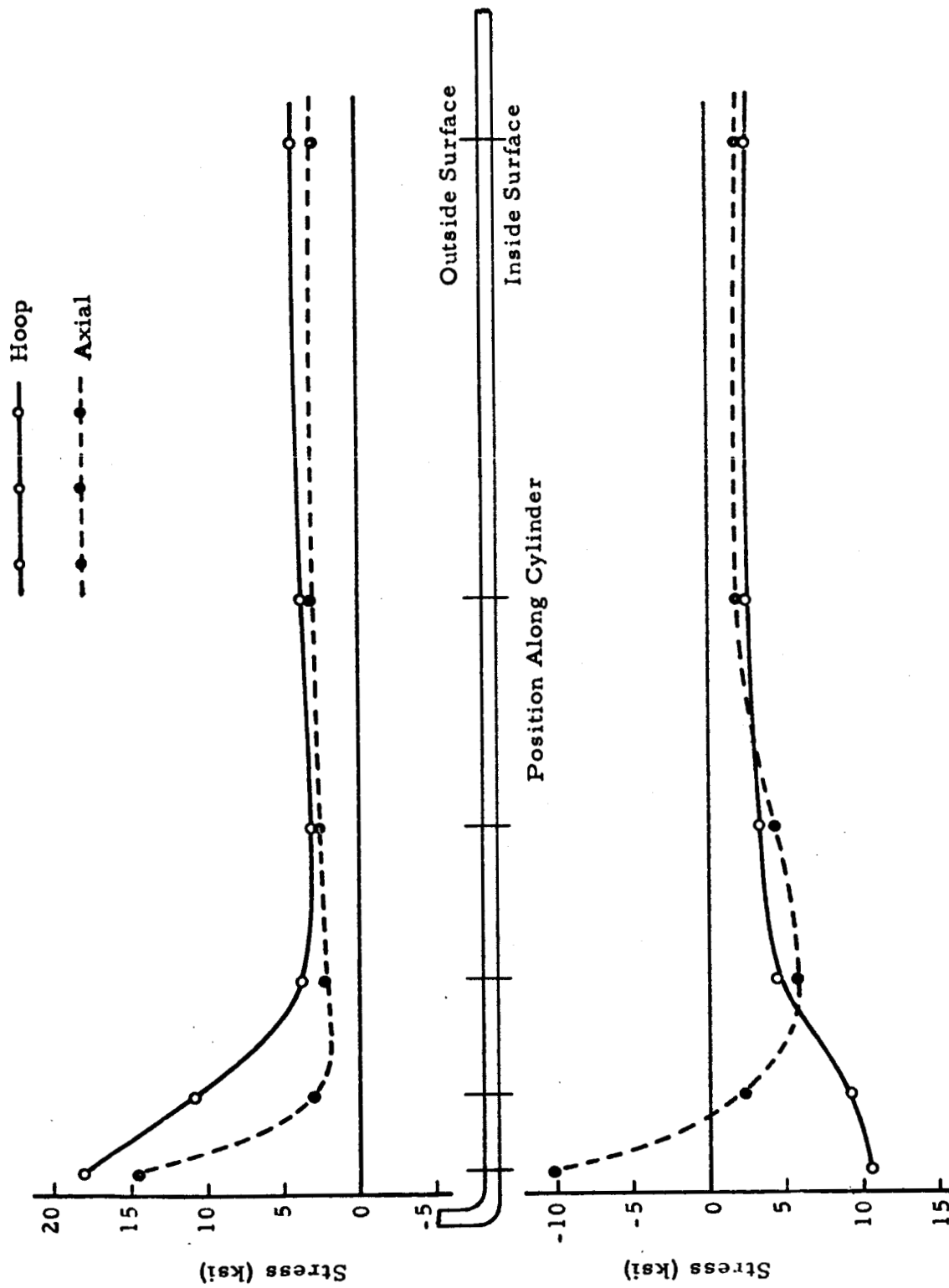


FIG. 3 STRESS DISTRIBUTION ALONG THE LONGITUDINAL LINE OF THE CYLINDER FOR AN INTERNAL PRESSURE OF 30 PSI

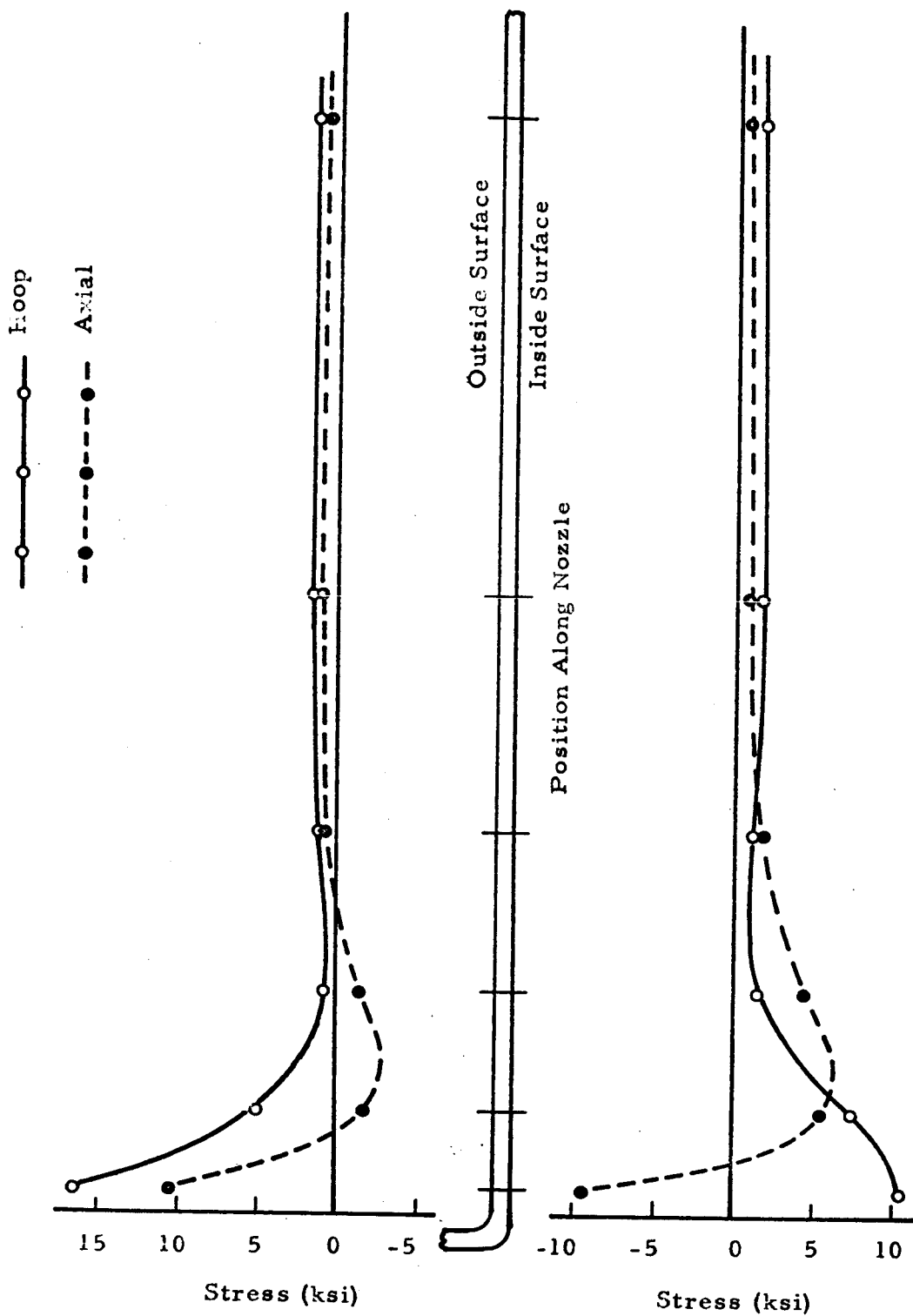


Fig. 9 STRESS DISTRIBUTION ALONG THE LONGITUDINAL
LINE OF THE NOZZLE FOR AN INTERNAL PRESSURE
OF 30 PSI

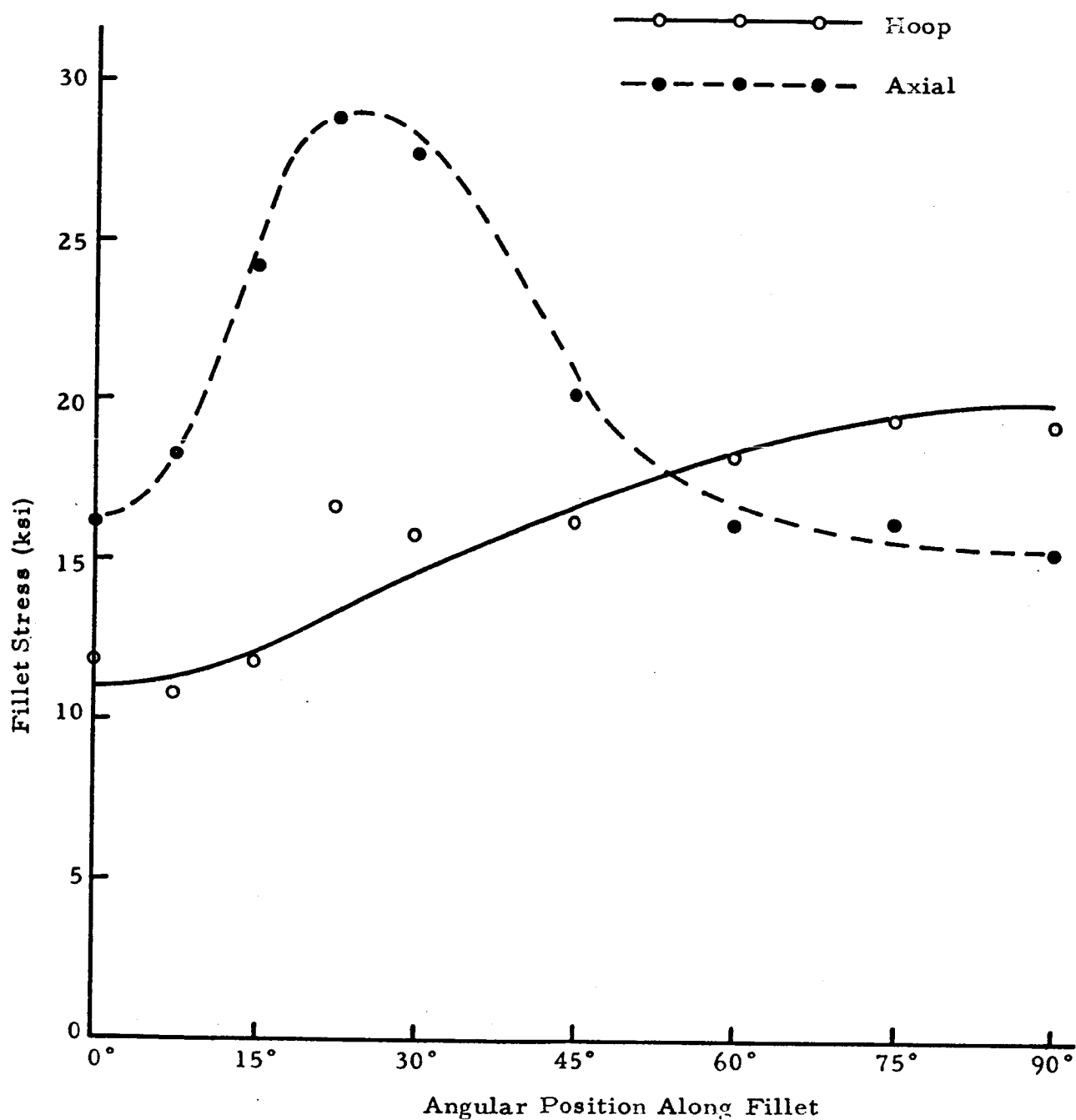


Fig. 10 STRESS DISTRIBUTION IN THE FILLET BETWEEN THE NOZZLE AND THE CYLINDER FOR AN INTERNAL PRESSURE OF 30 PSI

Table 7

PRINCIPAL STRESSES ON THE TRANSVERSE PLANE OF VESSEL C-1
FOR A THRUST (OUTWARD) OF 1000 LB ON THE NOZZLE

Gage No.	Gage Location	PRIMARY LINE				SECONDARY LINE					
		Outside		Inside		Outside		Inside			
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
1	Cylinder	- 0.4	+ 0.8	- 0.7	- 0.9	- 0.3	+ 0.6	- 0.6	- 0.8	-	-
2	Cylinder	- 2.0	- 1.6	- 1.1	+ 1.1	-	-	-	-	-	-
3	Cylinder	- 3.7	- 6.1	+ 1.3	+ 6.3	- 3.8	- 4.3	+ 0.8	+ 4.7	-	-
4	Cylinder	- 0.3	- 4.3	+ 2.9	+ 6.2	-	-	-	-	-	-
5	Cylinder	+ 3.5	+ 0.6	+ 2.0	+ 1.5	+ 3.2	+ 1.0	+ 1.7	+ 1.5	-	-
6	Cylinder	+ 7.0	+ 8.8	+ 0.5	- 6.0	-	-	-	-	-	-
7	Cylinder	+10.5	+13.5	- 2.3	-14.3	+ 8.9	+11.9	- 2.5	-16.2	-	-
9	Nozzle	+13.6	+13.5	-11.5	+ 2.0	+15.5	+11.0	-10.5	+ 2.5	-	-
10	Nozzle	- 1.0	+ 2.7	+ 4.5	+ 2.4	-	-	-	-	-	-
11	Nozzle	- 1.6	- 0.7	+ 3.0	+ 1.3	- 0.9	- 0.4	+ 2.8	+ 1.7	-	-
12	Nozzle	+ 0.6	- 0.5	+ 0.9	+ 0.1	-	-	-	-	-	-
13	Nozzle	+ 0.8	- 0.3	+ 0.7	+ 0.2	+ 0.7	+ 0.6	+ 0.8	+ 0.4	-	-
14	Nozzle	+ 0.7	- 0.2	+ 0.6	+ 0.1	-	-	-	-	-	-

Table 8

PRINCIPAL STRESSES ON THE LONGITUDINAL PLANE OF VESSEL C-1
FOR A THRUST (OUTWARD) OF 1000 LB ON THE NOZZLE

Gage No.	Gage Location	PRIMARY LINE				SECONDARY LINE					
		Outside		Inside		Outside		Inside			
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
23	Cylinder	+ 0.7	+ 0.5	+ 0.5	- 0.5	-	-	-	-	-	-
24	Cylinder	+ 0.8	+ 0.8	+ 0.7	- 0.3	-	-	-	-	-	-
25	Cylinder	+ 0.3	+ 0.6	+ 0.5	- 0.2	+ 0.6	+ 0.2	+ 0.4	- 0.2	- 0.2	- 0.2
26	Cylinder	+ 0.3	+ 0.3	+ 0.7	- 0.1	-	-	-	-	-	-
27	Cylinder	+ 0.3	+ 0.4	+ 1.0	+ 0.6	+ 0.4	+ 0.2	+ 1.3	+ 0.4	+ 0.4	+ 0.4
28	Cylinder	+ 0.8	+ 1.6	- 0.4	+ 0.9	-	-	-	-	-	-
29	Cylinder	+ 2.9	+ 2.7	- 3.0	+ 1.2	+ 3.1	+ 2.8	- 3.0	+ 0.9	+ 0.9	+ 0.9
31	Nozzle	+ 2.7	+ 2.6	- 3.0	+ 0.6	+ 3.3	+ 2.9	- 2.9	+ 0.8	+ 0.8	+ 0.8
32	Nozzle	+ 0.5	+ 1.1	+ 0.7	+ 0.3	-	-	-	-	-	-
33	Nozzle	- 0.2	+ 0.2	+ 0.5	- 0.1	- 0.4	+ 0.2	+ 0.6	- 0.1	- 0.1	- 0.1
34	Nozzle	+ 0.2	- 0.3	+ 0.3	- 0.1	-	-	-	-	-	-
35	Nozzle	+ 0.2	+ 0.1	+ 0.1	- 0.1	+ 0.1	+ 0.2	- 0.1	- 0.2	- 0.2	- 0.2
36	Nozzle	+ 0.2	+ 0.1	+ 0.2	- 0.1	-	-	-	-	-	-

Table 9
FILLET STRESSES IN VESSEL C-1 FOR A THRUST
(OUTWARD) OF 1000 LB ON THE NOZZLE

Gage No.	Gage Location	FILLET STRESS			
		Outside		Inside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
8	0°	+26.9	+16.1	- 9.7	+ 0.9
45	7-1/2°	+25.5	+14.9	-	-
46	15°	+22.3	+12.5	-	-
47	22-1/2°	+18.3	+11.7	-	-
48	30°	+17.5	+ 8.1	-	-
49	45°	+10.6	+ 5.9	-	-
50	60°	+ 4.7	+ 3.7	-	-
51	75°	+ 3.2	+ 2.8	-	-
30	90°	+ 3.0	+ 2.5	- 0.8	+ 1.0
19	180°	+25.2	+15.1	- 8.8	+ 0.9
41	270°	+ 2.8	+ 2.5	- 0.8	+ 1.1

Table 10

PRINCIPAL STRESSES ON THE TRANSVERSE PLANE OF VESSEL C-1
FOR A THRUST (INWARD) OF 1000 LB ON THE NOZZLE

Gage No.	Gage Location	PRIMARY LINE						SECONDARY LINE					
		Outside			Inside			Outside			Inside		
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
1	Cylinder	+ 0.3	- 1.0	+ 0.8	+ 1.0	+ 0.3	- 0.8	+ 0.3	- 0.8	+ 0.6	+ 0.8	+ 0.6	+ 0.8
2	Cylinder	+ 2.0	+ 1.7	+ 0.8	- 1.3	-	-	-	-	-	-	-	-
3	Cylinder	+ 3.2	+ 5.9	- 1.4	- 6.9	+ 2.6	+ 4.5	- 1.1	- 5.4	-	-	-	-
4	Cylinder	- 0.1	+ 4.1	- 3.3	- 6.8	-	-	-	-	-	-	-	-
5	Cylinder	- 4.0	- 1.7	- 2.6	- 1.6	- 3.0	- 2.2	- 1.8	- 1.8	-	-	-	-
6	Cylinder	- 7.4	- 9.6	- 0.5	+ 6.3	-	-	-	-	-	-	-	-
7	Cylinder	-12.3	-16.5	+ 2.1	+12.5	-10.7	-14.8	+ 1.7	+13.0	-	-	-	-
9	Nozzle	-11.3	-10.9	+10.2	- 2.2	- 9.7	-10.0	+ 9.8	- 2.8	-	-	-	-
10	Nozzle	+ 0.9	- 3.5	- 4.9	- 2.5	-	-	-	-	-	-	-	-
11	Nozzle	+ 1.3	+ 0.5	- 3.8	- 1.7	+ 1.1	+ 0.3	- 3.2	- 1.3	-	-	-	-
12	Nozzle	- 0.8	+ 0.3	- 0.8	- 0.3	-	-	-	-	-	-	-	-
13	Nozzle	- 0.6	+ 0.3	- 0.8	- 0.3	- 0.8	- 0.4	- 0.6	- 0.4	-	-	-	-
14	Nozzle	- 0.7	+ 0.2	- 0.7	- 0.2	-	-	-	-	-	-	-	-

Table 11

PRINCIPAL STRESSES ON THE LONGITUDINAL PLANE OF VESSEL C-1
FOR A THRUST (INWARD) OF 1000 LB ON THE NOZZLE

Gage No.	Gage Location	PRIMARY LINE			SECONDARY LINE					
		Outside		Inside		Outside		Inside		
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Hoop Stress (ksi)
23	Cylinder	- 0.8	- 0.7	- 0.4	+ 0.4	-	-	-	-	-
24	Cylinder	- 0.8	- 1.0	- 0.6	+ 0.2	-	-	-	-	-
25	Cylinder	- 0.6	- 0.6	- 0.5	+ 0.2	- 0.6	- 0.3	- 0.4	+ 0.2	-
26	Cylinder	- 0.5	- 0.5	- 0.8	+ 0.1	-	-	-	-	-
27	Cylinder	- 0.2	- 0.4	- 1.0	- 0.8	- 0.4	- 0.2	- 1.4	- 0.4	-
28	Cylinder	- 1.2	- 2.0	+ 0.2	- 1.0	-	-	-	-	-
29	Cylinder	- 3.1	- 2.8	+ 3.0	- 0.8	- 3.5	- 2.7	+ 2.8	- 0.7	-
31	Nozzle	- 2.6	- 3.2	+ 2.6	- 0.8	- 2.9	- 3.5	+ 2.8	- 0.8	-
32	Nozzle	- 0.5	- 1.0	- 0.5	- 0.2	-	-	-	-	-
33	Nozzle	+ 0.3	- 0.2	- 0.6	+ 0.1	+ 0.4	- 0.2	- 0.5	+ 0.1	-
34	Nozzle	- 0.3	+ 0.3	- 0.4	+ 0.2	-	-	-	-	-
35	Nozzle	- 0.2	- 0.2	- 0.1	+ 0.1	- 0.3	- 0.2	- 0.1	+ 0.2	-
36	Nozzle	+ 0.2	- 0.1	+ 0.1	+ 0.1	-	-	-	-	-

Table 12
FILLET STRESSES IN VESSEL C-1 FOR A THRUST
(INWARD) OF 1000 LB ON THE NOZZLE

Gage No.	Gage Location	FILLET STRESS			
		Outside		Inside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
8	0°	-27.8	-15.2	+ 9.3	- 1.0
45	7-1/2°	-26.9	-15.2	-	-
46	15°	-23.5	-14.9	-	-
47	22-1/2°	-21.7	-13.6	-	-
48	30°	-18.1	- 9.4	-	-
49	45°	-14.4	- 7.3	-	-
50	60°	- 4.5	- 4.0	-	-
51	75°	- 4.0	- 3.5	-	-
30	90°	- 3.3	- 3.0	+ 0.6	- 1.0
19	180°	-24.6	-14.6	+ 8.4	- 0.9
41	270°	- 3.0	- 2.8	+ 0.7	- 1.0

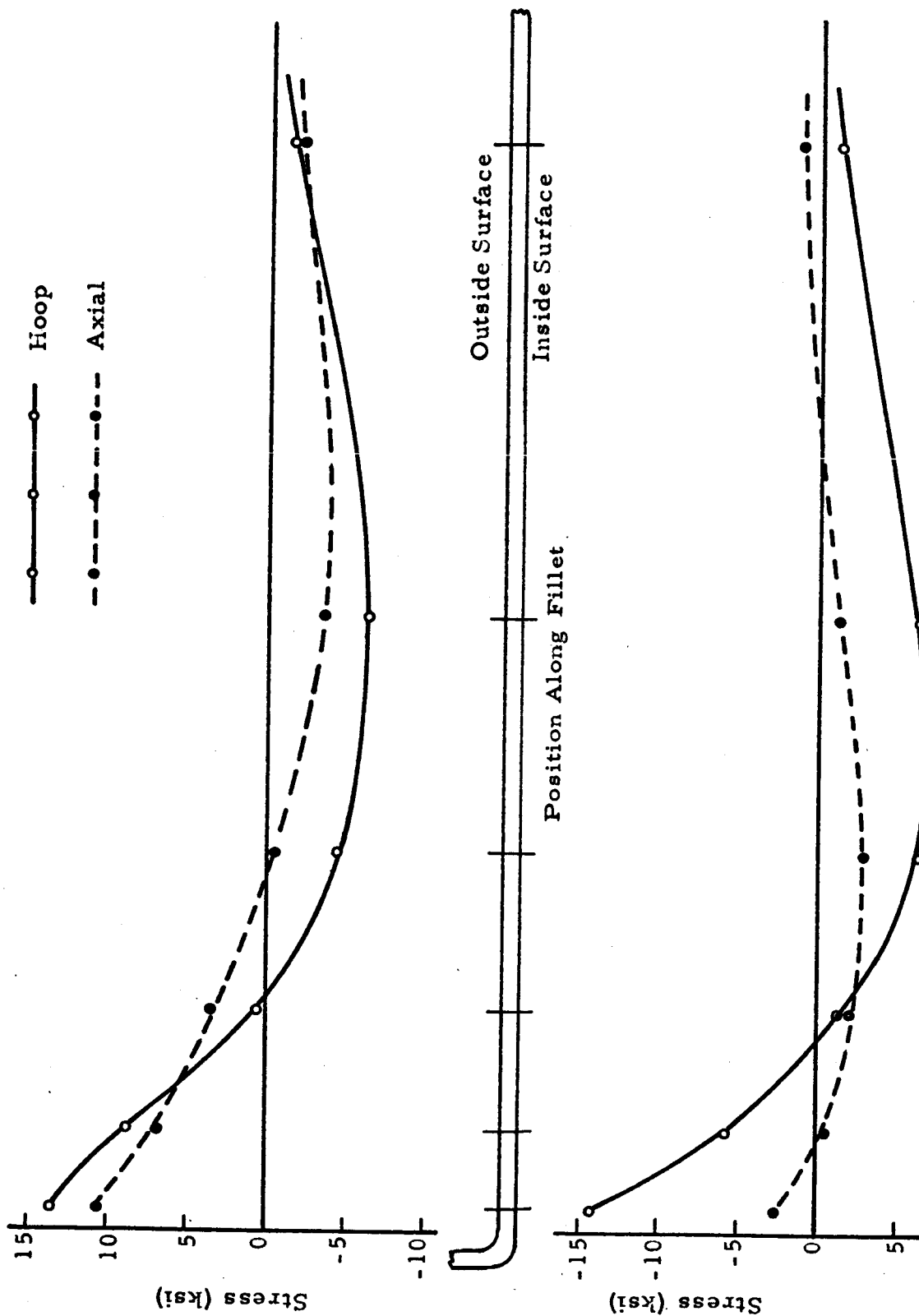


Fig. 11 STRESS DISTRIBUTION ALONG THE TRANSVERSE LINE OF THE CYLINDER FOR A THRUST (OUTWARD) OF 1000 LB ON THE NOZZLE

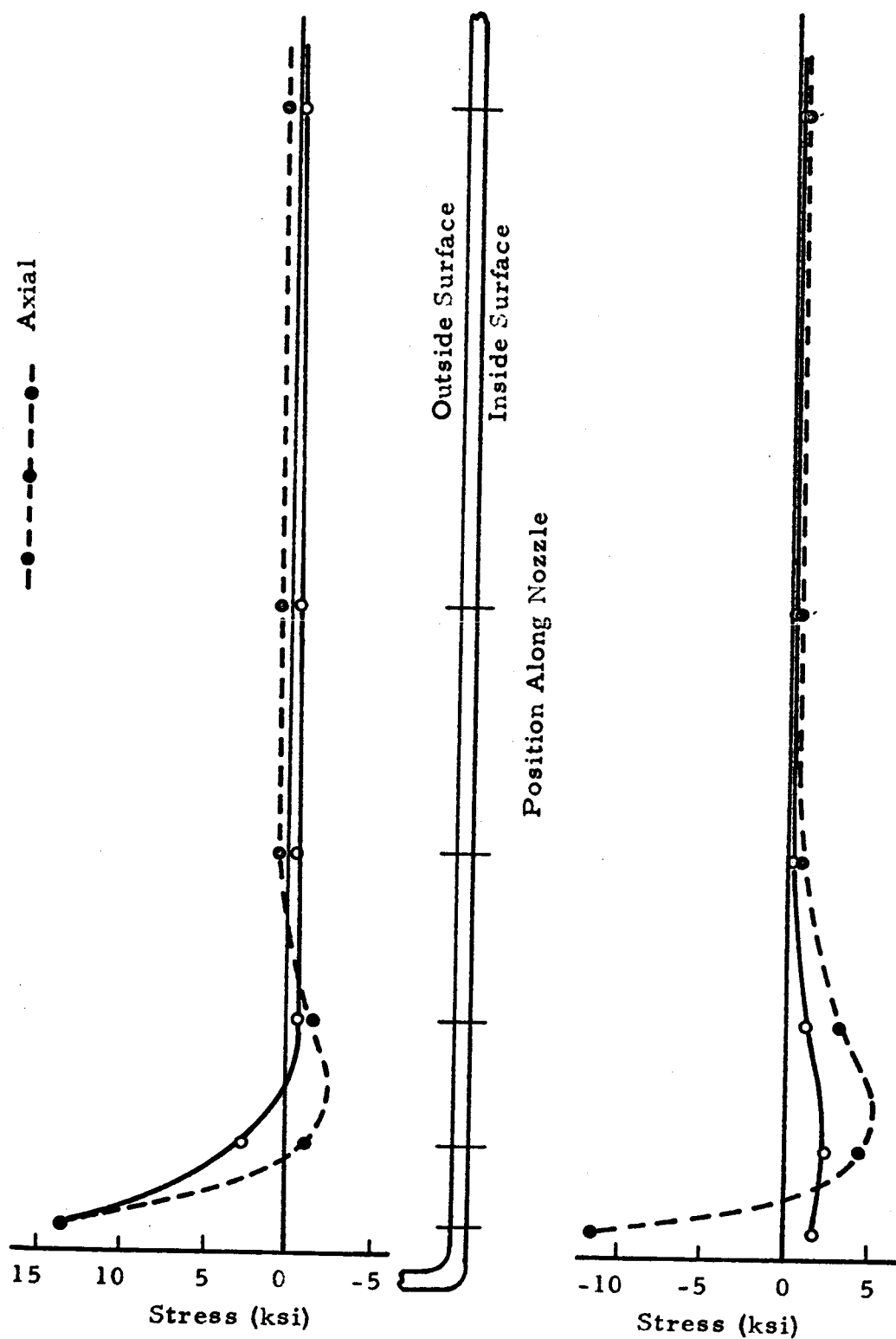


Fig. 12 STRESS DISTRIBUTION ALONG THE TRANSVERSE LINE OF THE NOZZLE FOR A THRUST (OUTWARD) OF 1000 LB ON THE NOZZLE

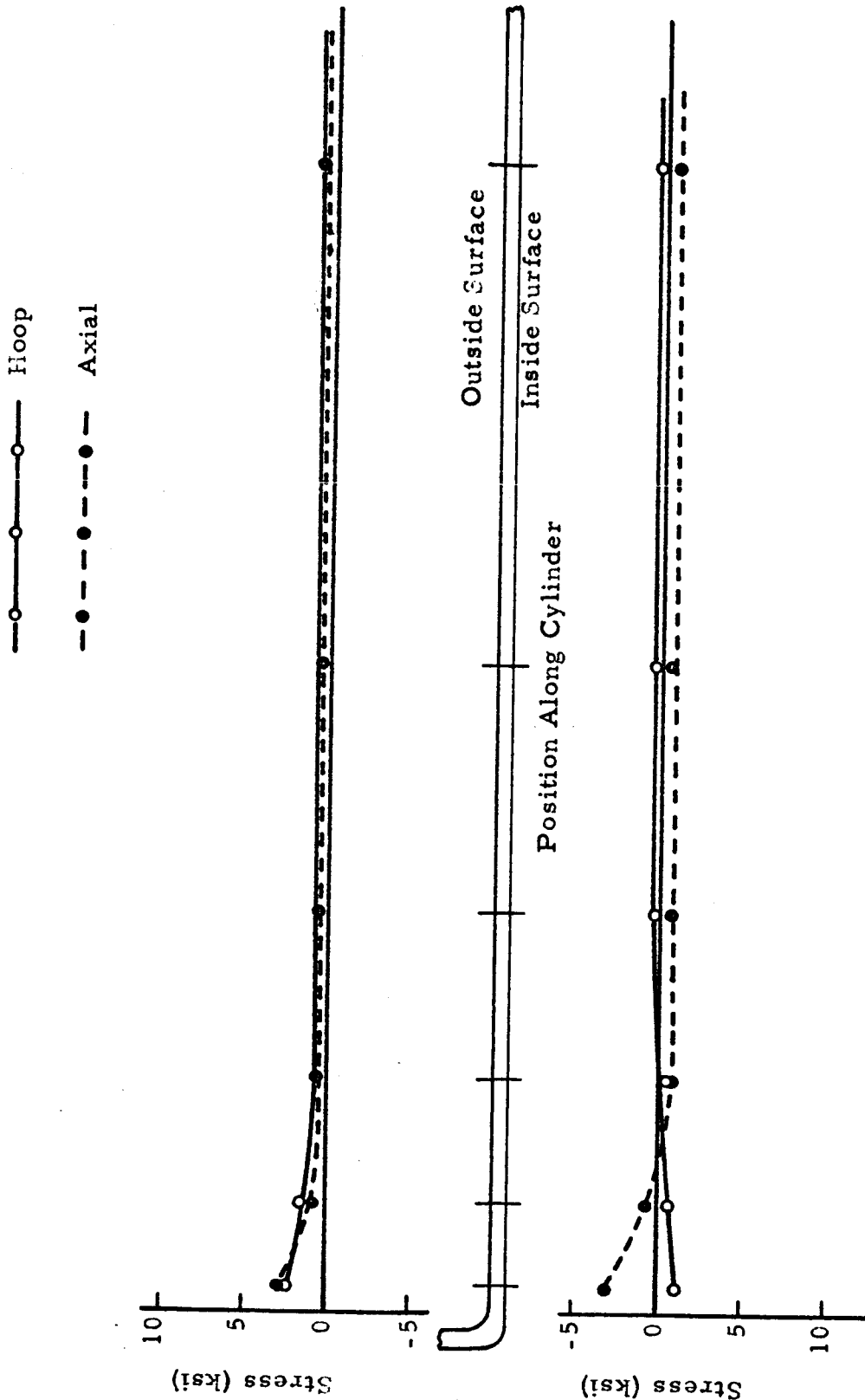


Fig. 13 STRESS DISTRIBUTION ALONG THE LONGITUDINAL LINE OF THE CYLINDER FOR A THRUST (OUTWARD) OF 1000 LB ON THE NOZZLE

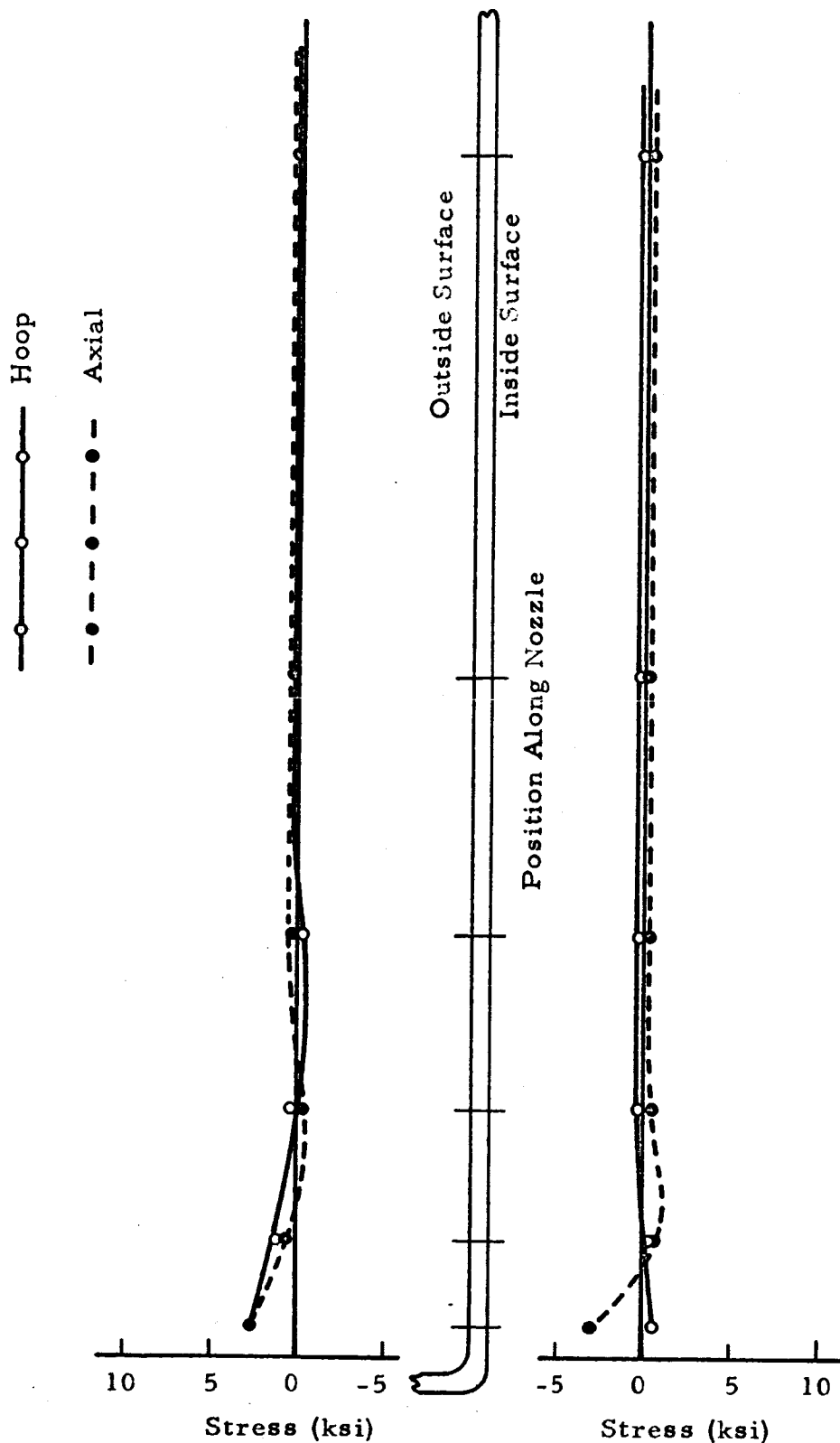


Fig. 14 STRESS DISTRIBUTION ALONG THE LONGITUDINAL LINE OF THE NOZZLE FOR A THRUST (OUTWARD) OF 1000 LB ON THE NOZZLE

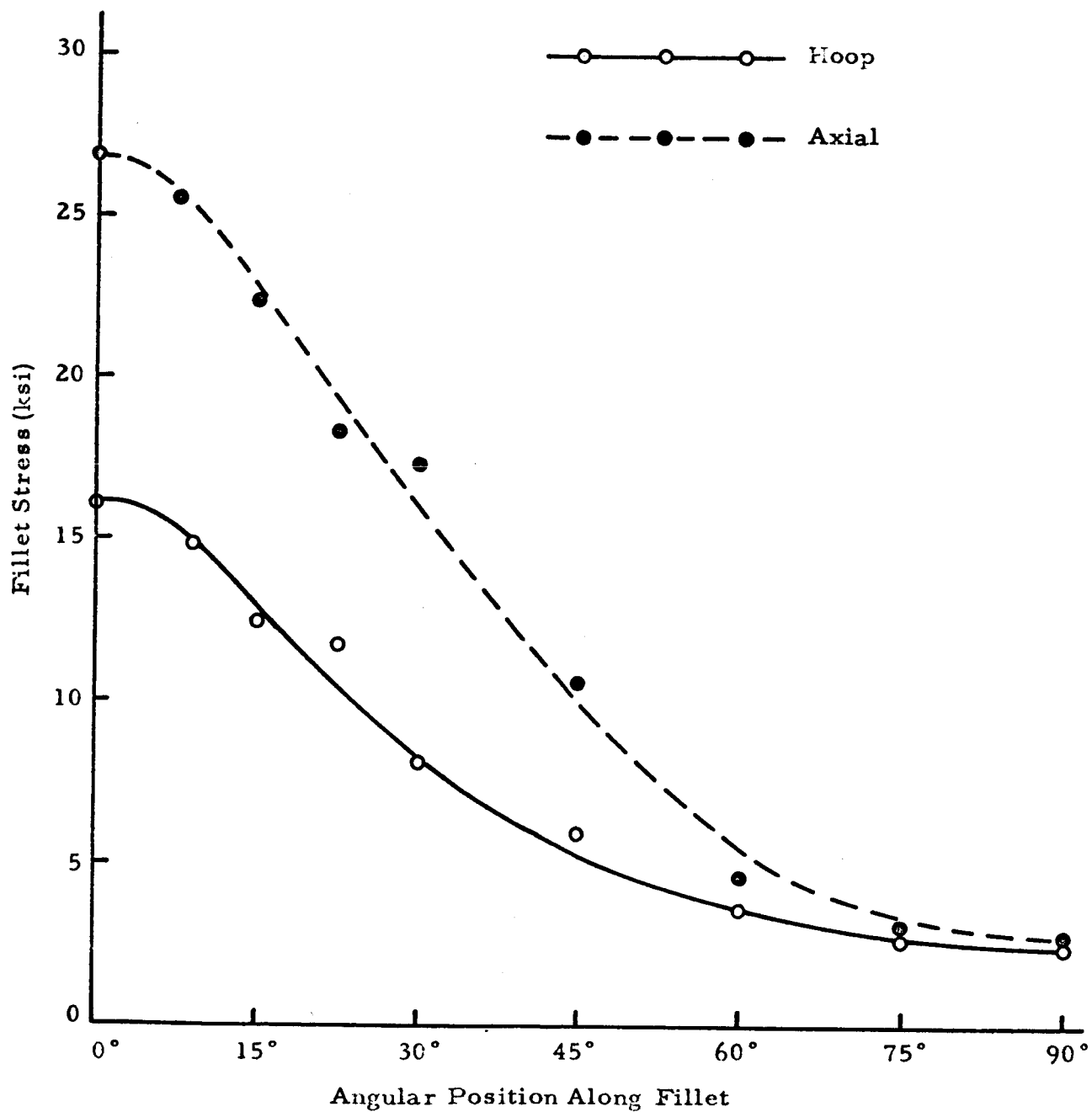


Fig. 15 STRESS DISTRIBUTION IN THE FILLET BETWEEN THE NOZZLE AND THE CYLINDER FOR A THRUST (OUTWARD) OF 1000 LB ON THE NOZZLE

Table 13

PRINCIPAL STRESSES ON THE TRANSVERSE PLANE OF VESSEL C-1 FOR A TRANSVERSE
MOMENT (CLOCKWISE COUPLE) OF 3000 IN-LB ON THE NOZZLE

Gage No.	Gage Location	PRIMARY LINE				SECONDARY LINE					
		Outside		Inside		Outside		Inside		Hoop Stress (ksi)	Hoop Stress (ksi)
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)		
1	Cylinder	+ 0.4	+ 1.1	+ 0.3	+ 0.7	- 0.5	- 0.8	- 0.1	- 0.4	-	-
2	Cylinder	- 0.9	- 1.2	+ 0.8	+ 2.1	-	-	-	-	-	-
3	Cylinder	- 1.2	- 3.1	+ 1.6	+ 4.0	+ 0.9	+ 3.3	- 2.3	- 4.8	-	-
4	Cylinder	+ 1.1	- 0.9	+ 1.8	+ 2.6	-	-	-	-	-	-
5	Cylinder	+ 3.3	+ 2.5	+ 0.6	- 1.1	- 3.6	- 3.8	- 0.6	+ 1.5	-	-
6	Cylinder	+ 5.4	+ 7.3	- 1.5	- 6.2	-	-	-	-	-	-
7	Cylinder	+ 7.5	+14.8	- 4.7	-13.5	- 7.8	-15.9	+ 4.5	+14.0	-	-
9	Nozzle	+11.1	+ 8.1	-10.0	+ 0.4	-11.3	- 7.8	+ 9.8	+ 0.7	-	-
10	Nozzle	+ 0.3	+ 2.3	+ 2.5	+ 0.6	-	-	-	-	-	-
11	Nozzle	- 1.1	- 0.3	+ 2.1	+ 0.9	+ 1.5	+ 0.5	- 2.2	- 0.6	-	-
12	Nozzle	+ 0.5	- 0.4	+ 0.4	- 0.2	-	-	-	-	-	-
13	Nozzle	+ 0.4	- 0.1	+ 0.4	- 0.1	+ 0.6	+ 0.1	- 0.4	- 0.1	-	-
14	Nozzle	+ 0.4	- 0.1	+ 0.4	- 0.1	-	-	-	-	-	-

Table 14

**FILLET STRESSES IN VESSEL C-1 FOR A TRANSVERSE MOMENT
(CLOCKWISE COUPLE) OF 3000 IN-LB ON THE NOZZLE**

Gage No.	Gage Location	FILLET STRESS			
		Outside		Inside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
8	0°	+25.5	+11.3	- 9.0	- 2.0
45	7-1/2°	+23.8	+ 9.3	-	-
46	15°	+19.4	+ 6.6	-	-
47	22-1/2°	+15.2	+ 6.1	-	-
48	30°	+11.8	+ 4.3	-	-
49	45°	+ 4.3	+ 3.3	-	-
50	60°	+ 1.1	+ 0.9	-	-
51	75°	+ 0.4	+ 0.2	-	-
30	90°	+ 0.2	+ 0.2	- 0.4	- 0.1
19	180°	-23.9	-10.3	+ 9.4	+ 1.8
41	270°	+ 0.3	+ 0.6	+ 0.3	+ 0.2

Table 15

PRINCIPAL STRESSES ON THE TRANSVERSE PLANE OF VESSEL C-1 FOR A TRANSVERSE
MOMENT (COUNTERCLOCKWISE COUPLE) OF 3000 IN-LB ON THE NOZZLE

Gage No.	Gage Location	PRIMARY LINE				SECONDARY LINE					
		Inside		Outside		Inside		Outside			
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
1	Cylinder	- 0.3	- 0.3	- 0.5	- 0.4	+ 0.2	+ 0.4	+ 0.4	+ 0.2	+ 0.4	+ 0.2
2	Cylinder	+ 1.2	+ 1.5	- 0.8	- 1.4	-	-	-	-	-	-
3	Cylinder	+ 1.2	+ 3.4	- 1.3	- 3.8	- 1.1	- 3.2	+ 1.5	+ 4.1	-	-
4	Cylinder	- 1.3	+ 1.3	- 1.6	- 2.4	-	-	-	-	-	-
5	Cylinder	- 3.5	- 2.7	- 0.7	+ 1.3	+ 3.9	+ 3.4	+ 0.4	- 1.8	-	-
6	Cylinder	- 5.2	- 7.7	+ 2.0	+ 6.0	-	-	-	-	-	-
7	Cylinder	- 7.1	-14.7	+ 4.7	+13.1	+ 7.9	+16.2	- 4.1	-14.3	-	-
9	Nozzle	-10.7	- 7.9	+10.4	+ 0.7	+ 9.7	+ 7.1	-10.9	- 0.4	-	-
10	Nozzle	- 0.2	- 2.2	- 2.4	- 0.9	-	-	-	-	-	-
11	Nozzle	+ 1.3	+ 0.4	- 2.2	- 0.9	- 2.0	- 1.1	+ 1.3	+ 0.6	-	-
12	Nozzle	+ 0.4	+ 0.6	+ 0.6	+ 0.2	-	-	-	-	-	-
13	Nozzle	- 0.4	+ 0.1	- 0.4	+ 0.2	- 0.5	+ 0.3	- 0.3	- 0.1	-	-
14	Nozzle	- 0.4	+ 0.1	- 0.4	+ 0.1	-	-	-	-	-	-

Table 16
**FILLET STRESSES IN VESSEL C-1 FOR A TRANSVERSE
 MOMENT (COUNTERCLOCKWISE COUPLE)
 OF 3000 IN-LB ON THE NOZZLE**

Gage No.	Gage Location	FILLET STRESS			
		Outside		Inside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
8	0°	-23.2	-10.9	+11.3	+ 2.4
45	7-1/2°	-22.6	- 8.6	-	-
46	15°	-20.2	- 7.4	-	-
47	22-1/2°	-16.6	- 6.6	-	-
48	30°	-11.5	- 4.1	-	-
49	45°	- 4.1	- 2.9	-	-
50	60°	- 1.3	- 1.0	-	-
51	75°	- 0.6	- 0.3	-	-
30	90°	+ 0.2	+ 0.5	+ 0.7	+ 0.3
19	180°	+22.8	+ 9.6	-10.7	- 1.8
41	270°	- 0.1	- 0.1	+ 0.3	- 0.1

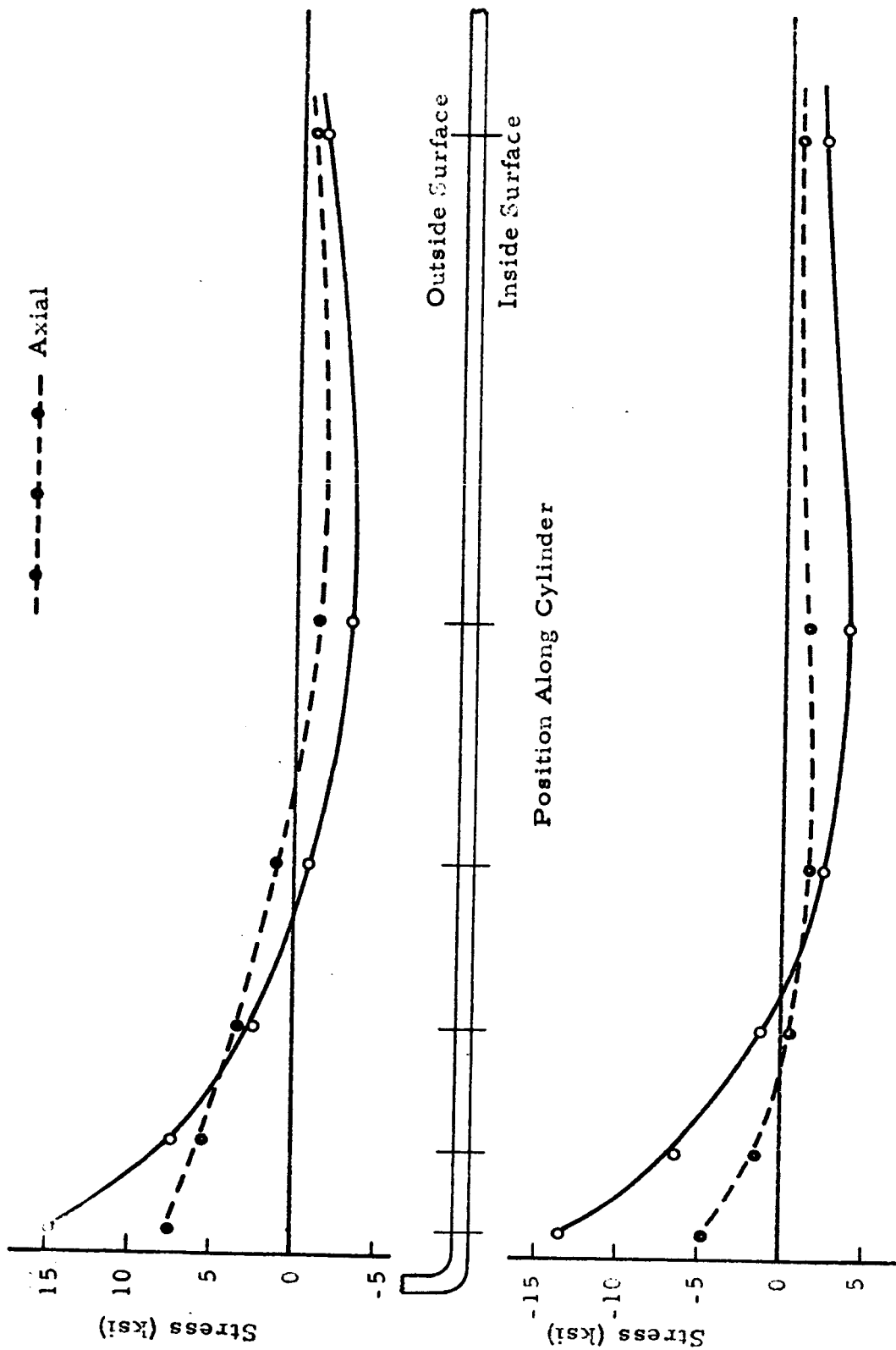


Fig. 16 STRESS DISTRIBUTION ALONG THE TRANSVERSE LINE OF THE CYLINDER FOR A TRANSVERSE MOMENT (CLOCKWISE COUPLE) OF 3000 IN.-LB ON THE NOZZLE

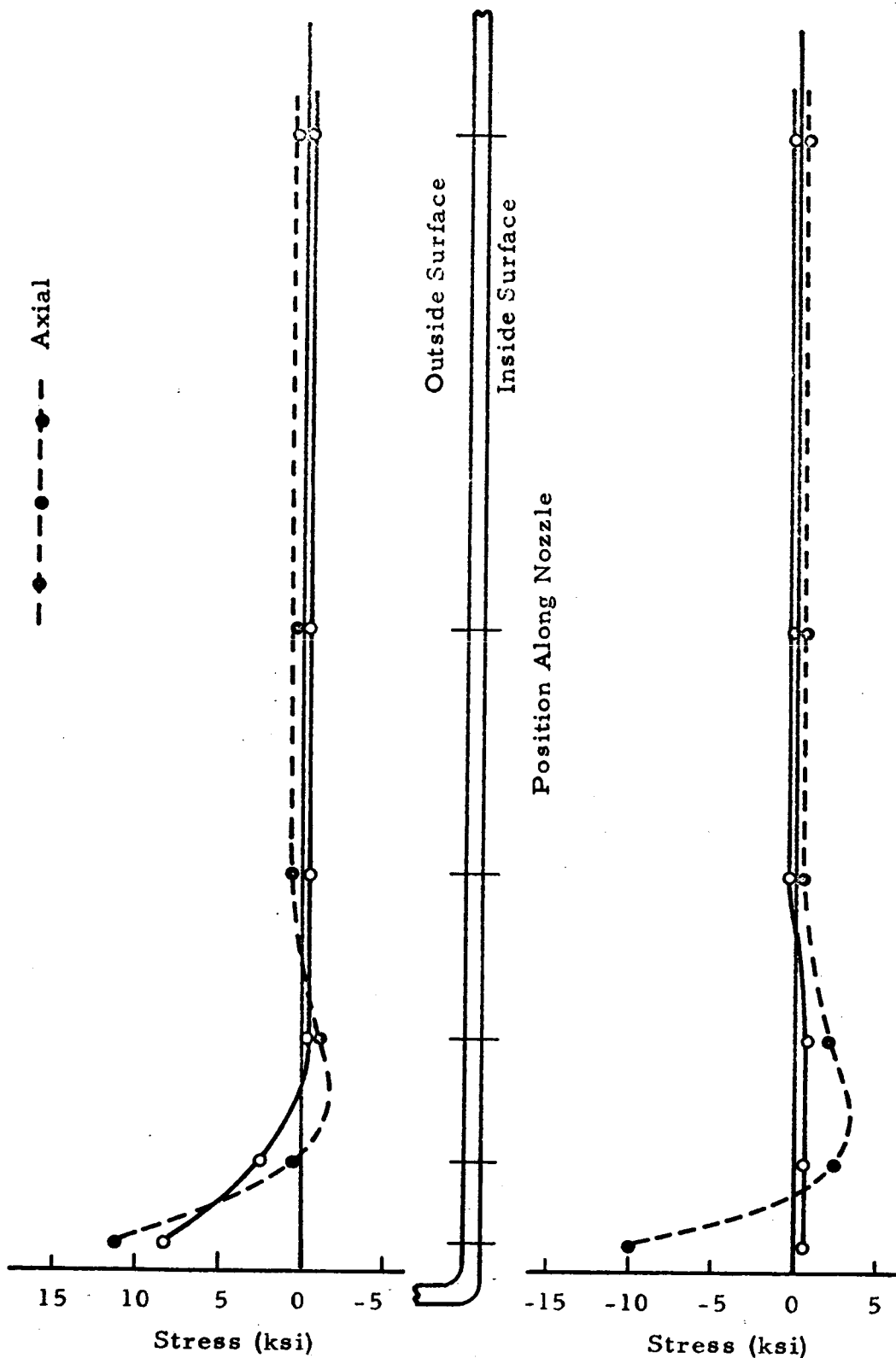


Fig. 17 STRESS DISTRIBUTION ALONG THE TRANSVERSE LINE OF THE NOZZLE FOR A TRANSVERSE MOMENT (CLOCKWISE COUPLE) OF 3000 IN-LB ON THE NOZZLE

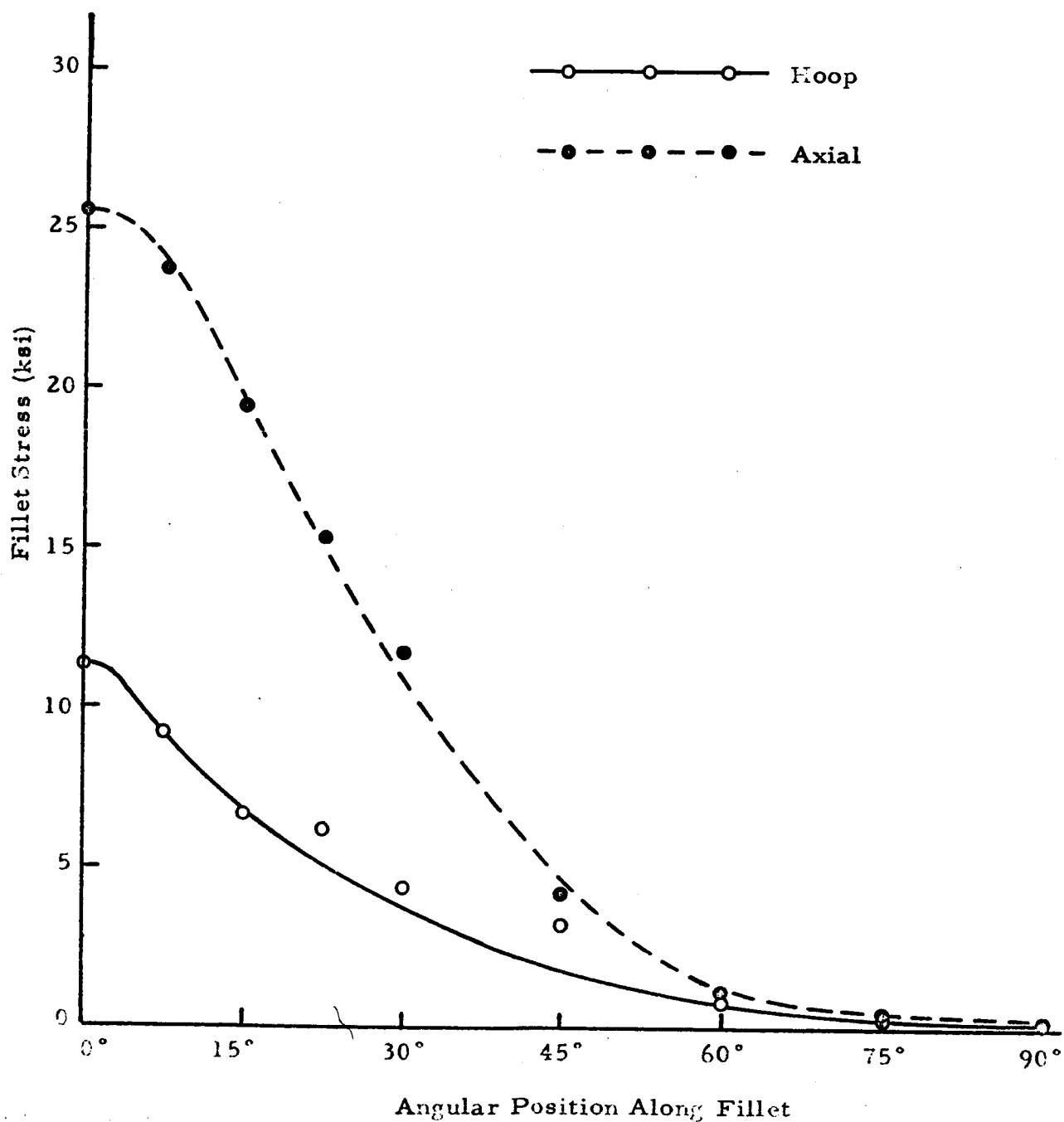


Fig. 13 STRESS DISTRIBUTION IN THE FILLET BETWEEN THE NOZZLE AND THE CYLINDER FOR A TRANSVERSE MOMENT (CLOCKWISE COUPLE) OF 3000 IN-LB ON THE NOZZLE

Table 17

PRINCIPAL STRESSES ON THE LONGITUDINAL PLANE OF VESSEL C-1 FOR A
LONGITUDINAL MOMENT (CLOCKWISE COUPLE) OF
18000 IN-LB ON THE NOZZLE

Gage No.	Gage Location	PRIMARY LINE				SECONDARY LINE					
		Inside		Outside		Inside		Outside		Hoop Stress (ksi)	Hoop Stress (ksi)
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)		
23	Cylinder	+ 0.8	+ 1.0	+ 0.4	- 1.2	-	-	-	-	-	-
24	Cylinder	+ 1.6	+ 1.3	+ 0.6	- 1.8	-	-	-	-	-	-
25	Cylinder	+ 1.5	+ 2.5	+ 1.1	- 1.5	- 1.5	- 2.5	- 1.0	+ 1.7	+ 1.7	+ 1.7
26	Cylinder	+ 1.1	+ 0.6	+ 2.6	- 1.3	-	-	-	-	-	-
27	Cylinder	+ 1.3	+ 1.6	+ 3.4	+ 1.5	+ 0.9	- 1.6	- 5.1	- 1.4	- 1.4	- 1.4
28	Cylinder	+ 2.6	+ 5.7	+ 0.5	+ 3.6	-	-	-	-	-	-
29	Cylinder	+13.7	+11.0	- 9.6	+ 3.1	-14.9	-12.8	+11.9	- 2.5	- 2.5	- 2.5
31	Nozzle	+11.2	+11.9	-11.4	+ 3.0	-12.9	-12.8	+12.1	- 2.9	- 2.9	- 2.9
32	Nozzle	- 0.5	+ 3.5	+ 3.1	+ 2.0	-	-	-	-	-	-
33	Nozzle	- 0.6	+ 0.8	+ 2.9	+ 0.6	+ 0.6	- 0.5	- 3.1	- 0.2	- 0.2	- 0.2
34	Nozzle	+ 1.0	+ 0.5	+ 1.0	- 0.3	-	-	-	-	-	-
35	Nozzle	+ 1.4	+ 0.5	+ 1.2	- 0.4	- 1.3	- 0.5	- 1.0	+ 0.5	+ 0.5	+ 0.5
36	Nozzle	+ 1.6	+ 0.4	+ 1.4	- 0.2	-	-	-	-	-	-

Table 18

**FILLET STRESSES IN VESSEL C-1 FOR A LONGITUDINAL MOMENT
(CLOCKWISE COUPLE) OF 18000 IN-LB ON THE NOZZLE**

Gage No.	Gage Location	FILLET STRESS			
		Outside		Inside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
8	0°	+ 2.9	+ 1.1	+ 0.2	+ 1.3
45	7-1/2°	+ 6.3	+ 3.3	-	-
46	15°	+18.4	+ 6.3	-	-
47	22-1/2°	+27.5	+12.2	-	-
48	30°	+29.5	+16.0	-	-
49	45°	+21.8	+17.8	-	-
50	60°	+15.1	+12.7	-	-
51	75°	+12.8	+11.8	-	-
30	90°	+12.1	+11.8	- 2.1	+ 4.1
19	180°	+ 2.2	+ 1.2	+ 0.2	+ 1.2
41	270°	-13.3	-12.1	+ 2.8	- 5.9

Table 19

PRINCIPAL STRESSES ON THE LONGITUDINAL PLANE OF VESSEL C-1 FOR A
LONGITUDINAL MOMENT (COUNTERCLOCKWISE COUPLE) OF
18000 IN-LB ON THE NOZZLE

Gage No.	Gage Location	PRIMARY LINE				SECONDARY LINE					
		Inside		Outside		Inside		Outside			
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
23	Cylinder	- 0.8	- 0.9	- 0.5	+ 1.2	-	-	-	-	-	-
24	Cylinder	- 1.8	- 1.2	- 0.7	+ 1.7	-	-	-	-	-	-
25	Cylinder	- 1.5	- 2.8	- 0.9	+ 1.9	+ 1.4	+ 2.8	+ 1.5	- 1.6	-	-
26	Cylinder	- 1.5	- 0.8	- 2.5	+ 1.3	-	-	-	-	-	-
27	Cylinder	- 1.5	- 1.4	- 3.9	- 1.1	- 0.7	+ 1.3	+ 5.5	+ 1.3	-	-
28	Cylinder	- 2.1	- 5.4	+ 0.3	- 3.1	-	-	-	-	-	-
29	Cylinder	-13.4	-11.4	+ 9.6	- 3.5	+14.1	+12.5	-12.3	+ 2.7	-	-
31	Nozzle	-10.8	-12.0	+12.9	- 2.9	+12.5	+12.5	-12.5	+ 2.3	-	-
32	Nozzle	+ 0.7	- 3.9	- 3.3	- 2.3	-	-	-	-	-	-
33	Nozzle	+ 0.5	- 0.7	- 3.1	- 0.4	- 0.4	+ 0.6	+ 3.2	+ 0.4	-	-
34	Nozzle	- 1.0	- 0.5	- 1.5	+ 0.3	-	-	-	-	-	-
35	Nozzle	- 1.4	- 0.4	- 1.2	+ 0.2	+ 1.4	+ 0.3	+ 1.0	- 0.2	-	-
36	Nozzle	- 1.4	- 0.5	- 1.5	+ 0.2	-	-	-	-	-	-

Table 20
**FILLET STRESSES IN VESSEL C-1 FOR A LONGITUDINAL
 MOMENT (COUNTERCLOCKWISE COUPLE)
 OF 18000 IN-LB ON THE NOZZLE**

Gage No.	Gage Location	FILLET STRESS			
		Outside		Inside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
8	0°	- 1.1	- 0.2	+ 0.6	+ 1.1
45	7-1/2°	-10.7	- 6.1	-	-
46	15°	-22.0	- 8.4	-	-
47	22-1/2°	-29.8	-17.5	-	-
48	30°	-29.5	-15.8	-	-
49	45°	-21.8	-17.7	-	-
50	60°	-15.3	-13.0	-	-
51	75°	-13.3	-12.0	-	-
30	90°	-12.5	-11.5	+ 2.7	- 4.8
19	180°	- 0.1	+ 0.5	- 0.2	- 0.1
41	270°	+12.5	+11.9	- 2.9	+ 5.7

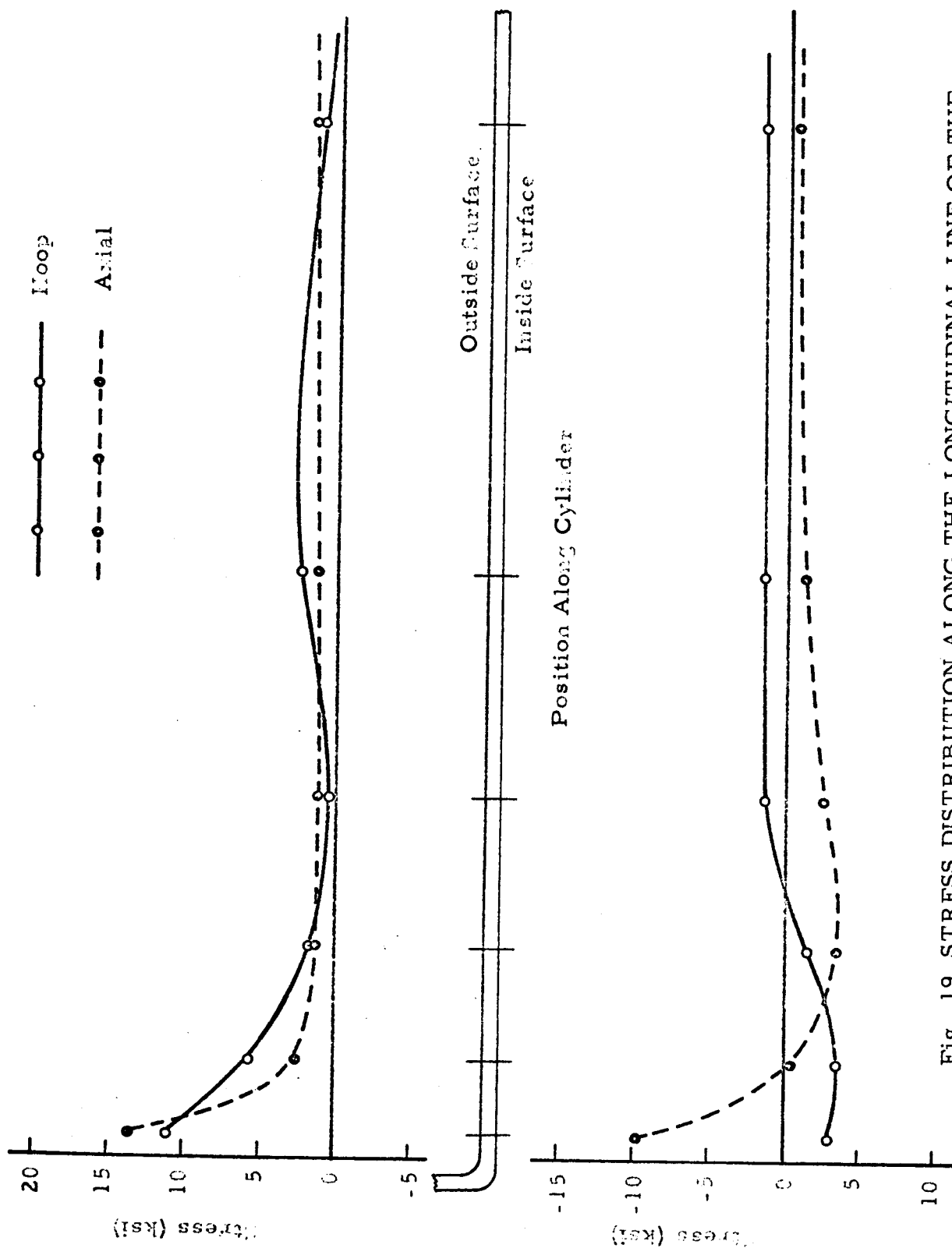


Fig. 19 STRESS DISTRIBUTION ALONG THE LONGITUDINAL LINE OF THE CYLINDER FOR A LONGITUDINAL MOMENT (CLOCKWISE COUPLE) OF 18000 IN-LB ON THE NOZZLE

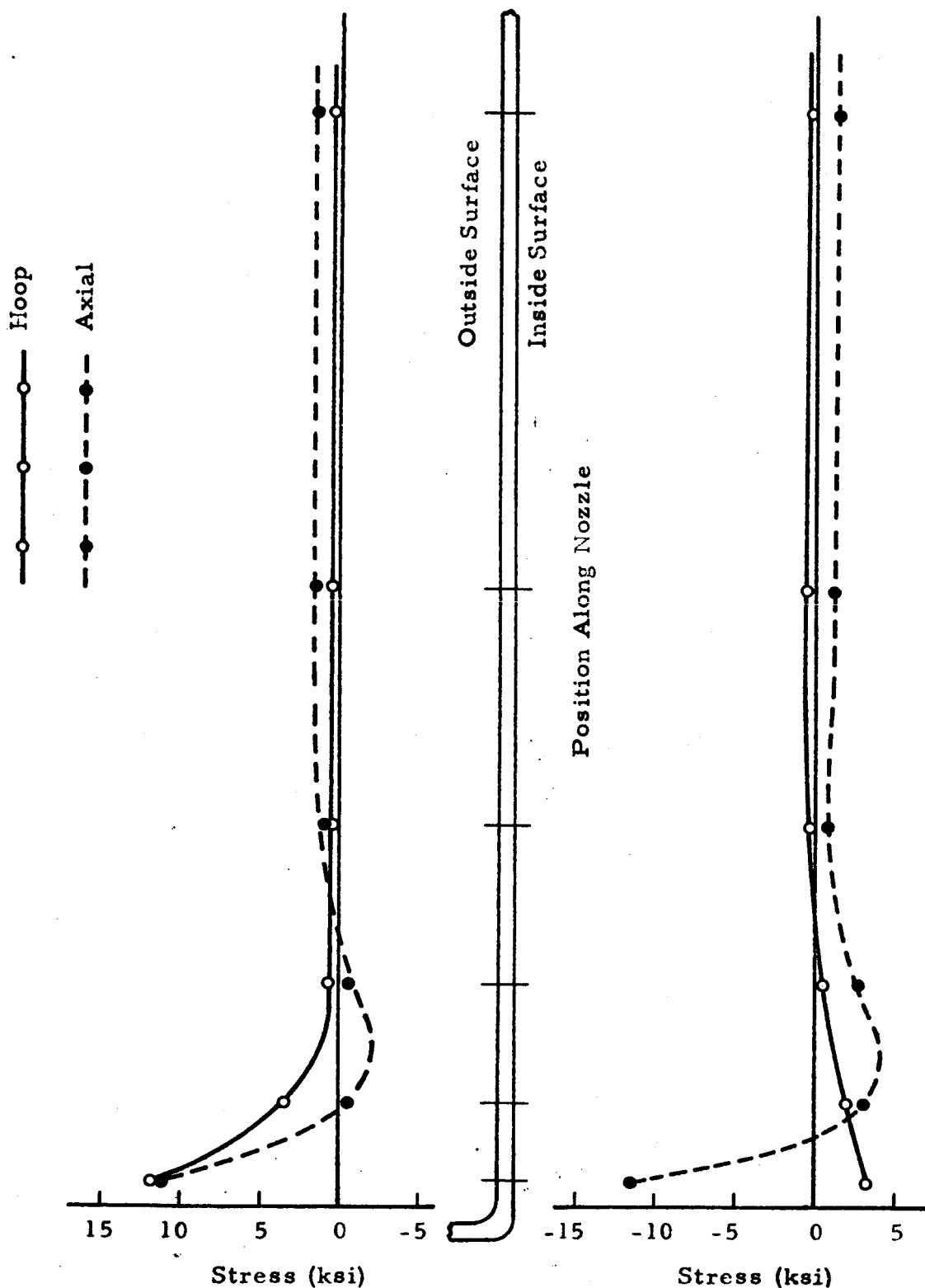


Fig. 20 STRESS DISTRIBUTION ALONG THE LONGITUDINAL LINE OF THE NOZZLE FOR A LONGITUDINAL MOMENT (CLOCKWISE COUPLE) OF 18000 IN-LB ON THE NOZZLE

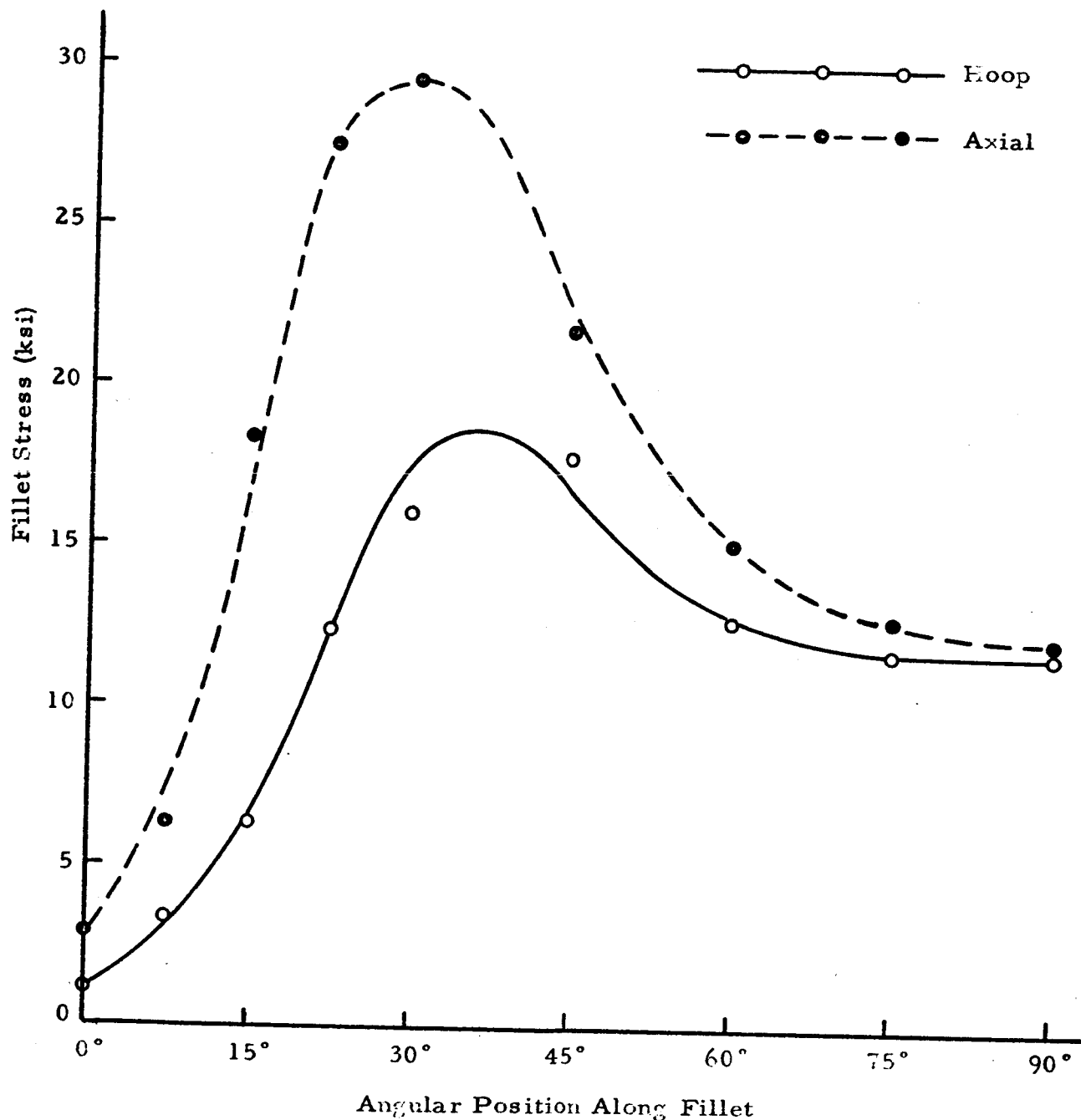


Fig. 21 STRESS DISTRIBUTION IN THE FILLET BETWEEN THE NOZZLE AND THE CYLINDER FOR A LONGITUDINAL MOMENT (CLOCKWISE COUPLE) OF 18000 IN-LB ON THE NOZZLE

Table 21

PRINCIPAL STRESSES ON THE TRANSVERSE PLANE OF VESSEL C-1 FOR AN
INTERNAL PRESSURE OF 15 PSI AND A TRANSVERSE
MOMENT (CLOCKWISE COUPLE) OF 3000 IN-LB

Gage No.	Gage Location	PRIMARY LINE				SECONDARY LINE			
		Inside		Outside		Inside		Outside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
1	Cylinder	+ 1.6	+ 2.8	+ 1.0	+ 1.1	+ 0.8	+ 1.6	+ 1.1	+ 1.1
2	Cylinder	- 2.1	- 0.9	+ 1.6	+ 5.4	-	-	-	-
3	Cylinder	- 1.9	- 5.0	+ 3.9	+ 8.7	+ 1.0	+ 1.7	- 0.5	+ 0.6
4	Cylinder	+ 3.5	- 0.8	+ 3.9	+ 5.8	-	-	-	-
5	Cylinder	+ 7.6	+ 5.6	+ 1.8	- 1.8	+ 1.1	+ 0.8	+ 0.5	- 0.1
6	Cylinder	+10.0	+12.2	- 5.9	- 5.7	-	-	-	-
7	Cylinder	+12.0	+19.3	- 4.4	-17.9	- 2.8	- 9.0	+ 4.0	+ 7.3
9	Nozzle	+14.0	+11.7	-12.9	+ 0.9	- 9.5	- 5.3	+ 7.0	+ 2.6
10	Nozzle	- 0.4	+ 4.0	+ 3.2	+ 2.0	-	-	-	-
11	Nozzle	- 2.1	+ 0.5	+ 2.5	+ 1.6	+ 1.1	+ 1.5	- 2.2	- 0.2
12	Nozzle	+ 0.3	+ 0.2	+ 0.4	+ 0.1	-	-	-	-
13	Nozzle	+ 0.5	+ 0.8	+ 0.6	+ 0.7	+ 0.9	+ 0.9	- 0.2	+ 0.8
14	Nozzle	+ 0.1	+ 1.1	+ 0.2	+ 0.5	-	-	-	-

Table 22

FILLET STRESSES IN VESSEL C-1 FOR AN INTERNAL PRESSURE
OF 15 PSI AND A TRANSVERSE MOMENT
(CLOCKWISE COUPLE) OF 3000 IN-LB

Gage No.	Gage Location	FILLET STRESS			
		Outside		Inside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
8	0°	+32.5	+16.9	-11.9	- 1.6
45	7-1/2°	+30.1	+14.1	-	-
46	15°	+30.7	+11.9	-	-
47	22-1/2°	+29.5	+15.8	-	-
48	30°	+24.9	+12.0	-	-
49	45°	+14.1	+12.1	-	-
50	60°	+ 9.1	+10.0	-	-
51	75°	+ 8.0	+10.2	-	-
30	90°	+ 7.5	+ 9.9	- 2.0	+ 6.5
19	180°	-17.2	- 5.4	+ 6.8	+ 2.5
41	270°	+ 7.0	+10.1	- 1.0	+ 8.0

Table 23

PRINCIPAL STRESSES IN VESSEL S-1 FOR AN
INTERNAL PRESSURE OF 60 PSI

Gage No.	Gage Location	PRIMARY LINE				SECONDARY LINE			
		Inside		Outside		Inside		Outside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
Lower									
1	Cylinder	+ 2.7	+ 4.9	+ 2.8	+ 5.5	+ 2.6	+ 5.5	+ 2.6	+ 5.9
2	Hemisphere	+ 2.4	+ 3.6	+ 3.0	+ 3.9	-	-	-	-
3	Hemisphere	+ 1.7	+ 3.0	+ 4.0	+ 3.0	+ 1.5	+ 3.2	+ 4.2	+ 2.9
4	Hemisphere	+ 0.5	+ 2.3	+ 4.5	+ 3.9	-	-	-	-
5	Hemisphere	+ 0.7	+ 4.2	+ 4.8	+ 6.4	+ 0.5	+ 4.6	+ 4.4	+ 6.8
6	Hemisphere	+ 4.7	+ 8.6	+ 4.6	+ 8.9	-	-	-	-
7	Hemisphere	+11.0	+14.8	- 6.8	+10.4	+10.5	+14.3	- 7.5	+10.9
9	Nozzle	+ 7.1	+13.7	- 6.8	+10.3	+ 6.6	+12.5	- 6.0	+11.0
10	Nozzle	+ 3.2	+ 4.6	+ 4.9	+ 4.5	-	-	-	-
11	Nozzle	+ 1.1	+ 2.3	+ 4.6	+ 4.3	+ 1.5	+ 2.6	+ 5.3	+ 4.5
12	Nozzle	+ 1.2	+ 1.7	+ 2.9	+ 3.6	-	-	-	-
13	Nozzle	+ 1.8	+ 2.5	+ 3.3	+ 4.3	+ 1.5	+ 2.7	+ 3.4	+ 4.6
14	Nozzle	+ 2.2	+ 1.9	+ 2.1	+ 4.6	-	-	-	-

Table 24
 FILLET STRESSES IN VESSEL S-1 FOR AN
 INTERNAL PRESSURE OF 60 PSI

Gage No.	Gage Location	FILLET STRESS			
		Outside		Inside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
8	0°	+19.6	+18.4	- 2.3	+12.6
23	15°	+18.4	+19.3	-	-
24	30°	+20.2	+22.2	-	-
25	45°	+23.1	+20.3	-	-
26	60°	+19.7	+21.6	-	-
27	75°	+21.8	+22.4	-	-
28	90°	+21.4	+20.4	-	-
19	180°	+18.9	+18.0	- 1.9	+12.0

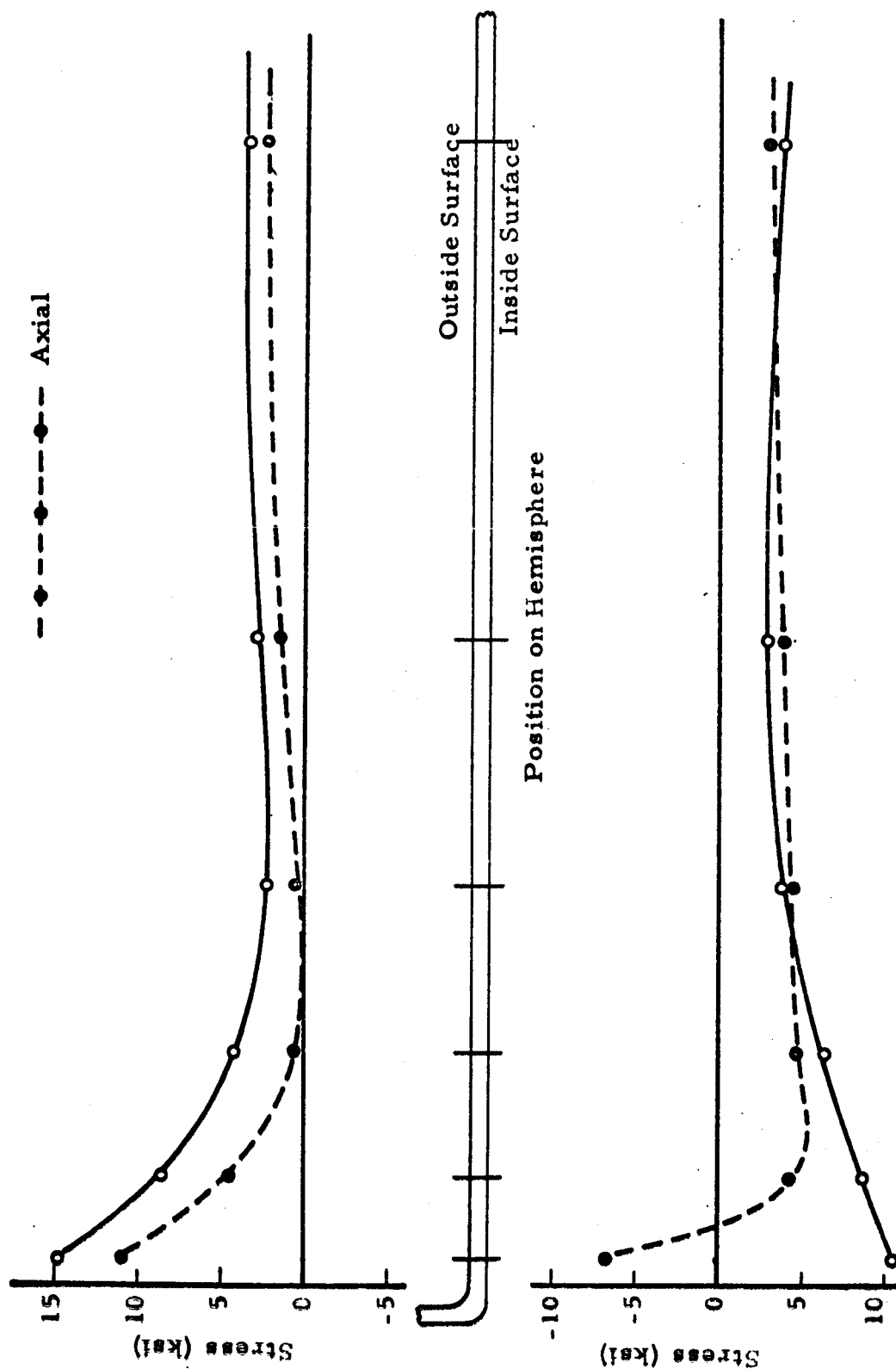


Fig. 22 STRESS DISTRIBUTION IN THE HEMISPHERE FOR AN
INTERNAL PRESSURE OF 60 PSI

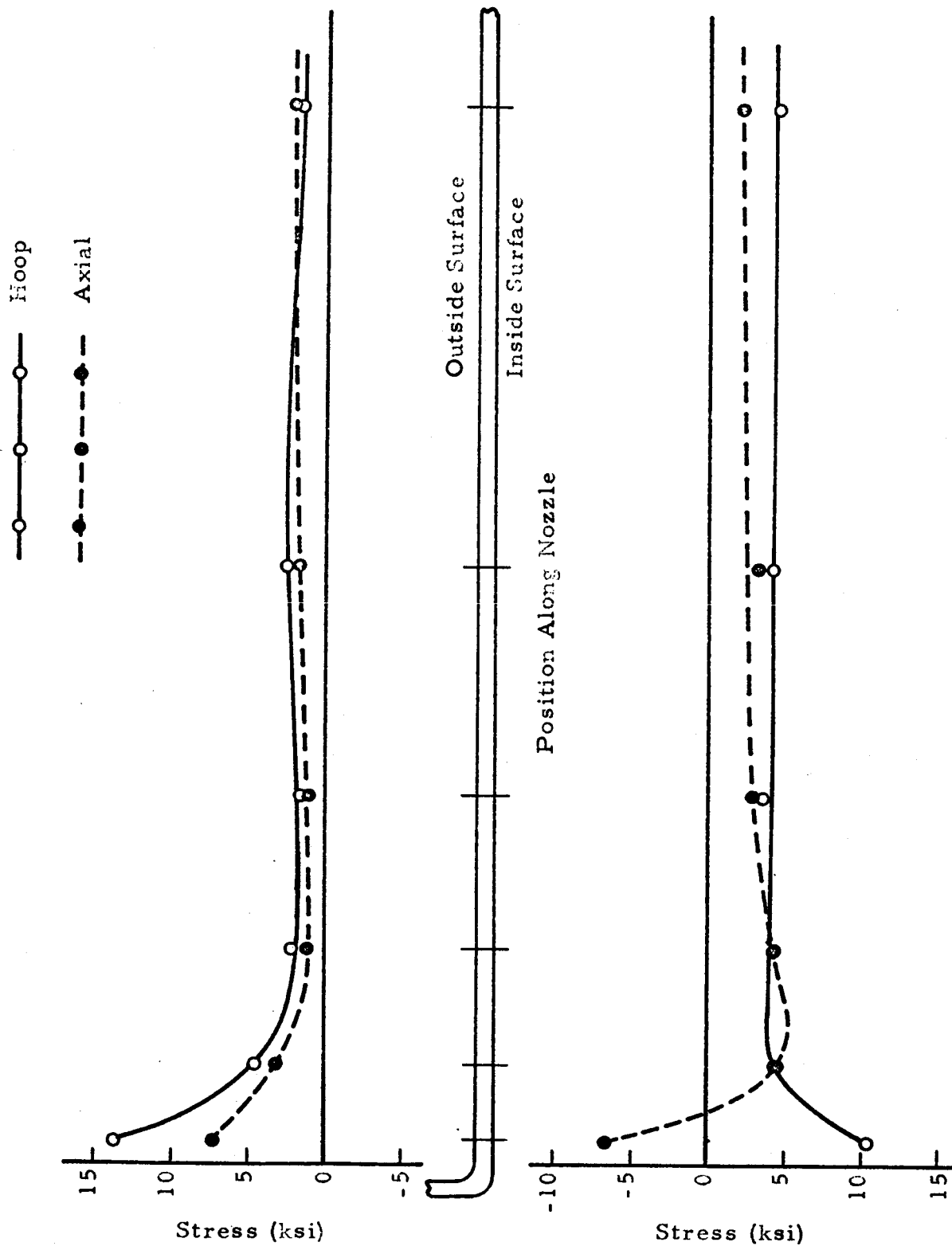


Fig. 23 STRESS DISTRIBUTION IN THE NOZZLE FOR AN
INTERNAL PRESSURE OF 60 PSI

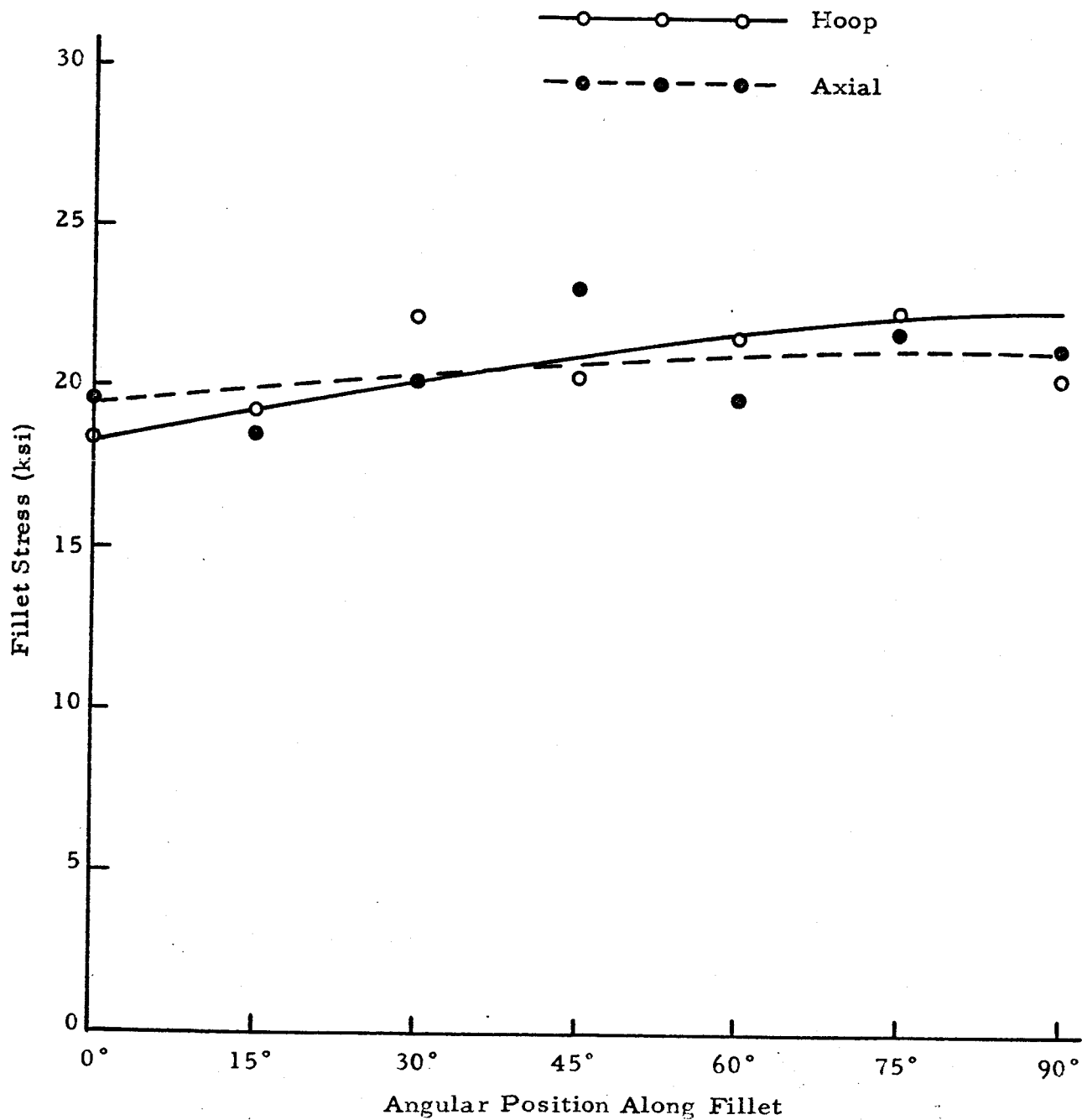


Fig. 24 STRESS DISTRIBUTION IN THE FILLET BETWEEN THE NOZZLE AND THE HEMISPHERE FOR AN INTERNAL PRESSURE OF 60 PSI

Table 25

PRINCIPAL STRESSES IN VESSEL S-1 FOR A THRUST
(OUTWARD) OF 6000 LB ON THE NOZZLE

Gage No.	Gage Location	PRIMARY LINE				SECONDARY LINE			
		Inside		Outside		Inside		Outside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
1	Lower Cylinder	+ 0.4	- 0.4	+ 0.8	+ 0.3	+ 0.4	- 0.4	+ 0.8	- 0.2
2	Hemisphere	+ 0.9	- 0.9	+ 0.8	- 1.5	-	-	-	-
3	Hemisphere	+ 1.1	- 1.9	+ 0.6	- 2.1	+ 0.8	- 1.5	+ 1.4	- 1.5
4	Hemisphere	+ 0.4	- 3.1	+ 2.9	- 2.4	-	-	-	-
5	Hemisphere	- 1.5	- 1.5	+ 4.3	- 1.1	- 1.4	- 1.4	+ 3.9	- 1.2
6	Hemisphere	+ 1.2	+ 1.1	+ 5.1	+ 3.0	-	-	-	-
7	Hemisphere	+ 9.5	+ 9.1	- 6.5	+ 3.9	+ 9.8	+ 8.6	- 5.3	+ 3.1
9	Nozzle	+ 8.2	+ 9.5	- 5.9	+ 4.9	+ 7.5	+ 8.4	- 6.2	+ 4.4
10	Nozzle	- 1.5	+ 2.3	- 3.8	+ 2.5	-	-	-	-
11	Nozzle	- 0.7	- 0.7	- 0.4	+ 0.3	- 1.2	- 0.9	- 0.3	+ 0.3
12	Nozzle	+ 0.8	- 0.2	+ 0.8	- 0.8	-	-	-	-
13	Nozzle	+ 1.1	+ 0.6	+ 0.8	+ 0.2	+ 0.9	+ 0.4	+ 0.9	+ 0.1
14	Nozzle	+ 1.7	+ 0.6	+ 1.7	+ 0.6	-	-	-	-

Table 26
 FILLET STRESSES IN VESSEL S-1 FOR A THRUST
 (OUTWARD) OF 6000 LB ON THE NOZZLE

Gage No.	Gage Location	FILLET STRESS			
		Outside		Inside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
8	0°	+20.6	+15.8	- 3.1	+ 6.3
23	15°	+20.7	+16.9	-	-
24	30°	+19.5	+18.3	-	-
25	45°	+23.5	+16.5	-	-
26	60°	+18.9	+16.4	-	-
27	75°	+21.2	+16.7	-	-
28	90°	+21.8	+16.1	-	-
19	180°	+19.1	+15.8	- 3.5	+ 5.8

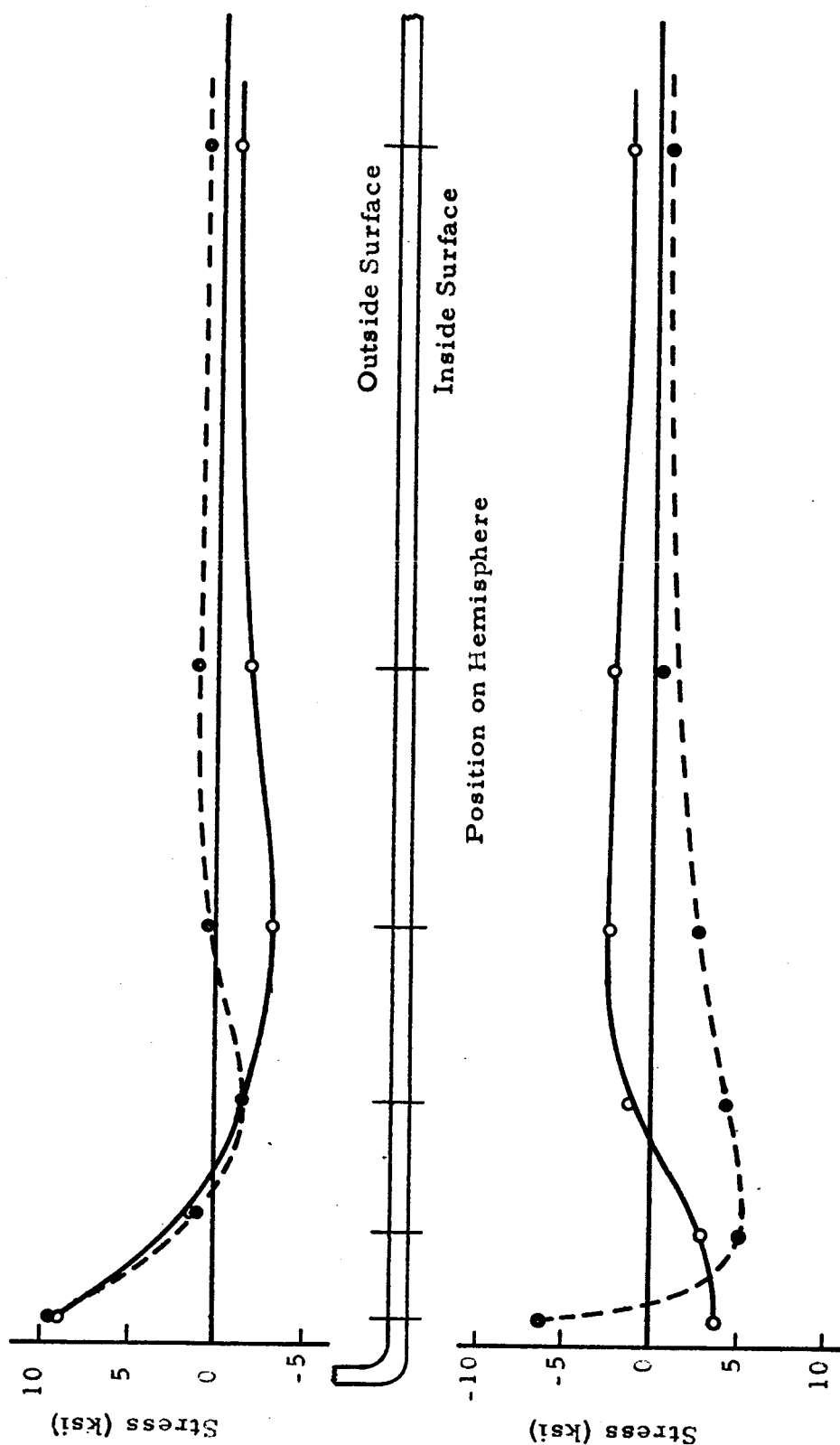


Fig. 25 STRESS DISTRIBUTION IN THE HEMISPHERE FOR A THRUST
(OUTWARD) OF 6000 LB ON THE NOZZLE

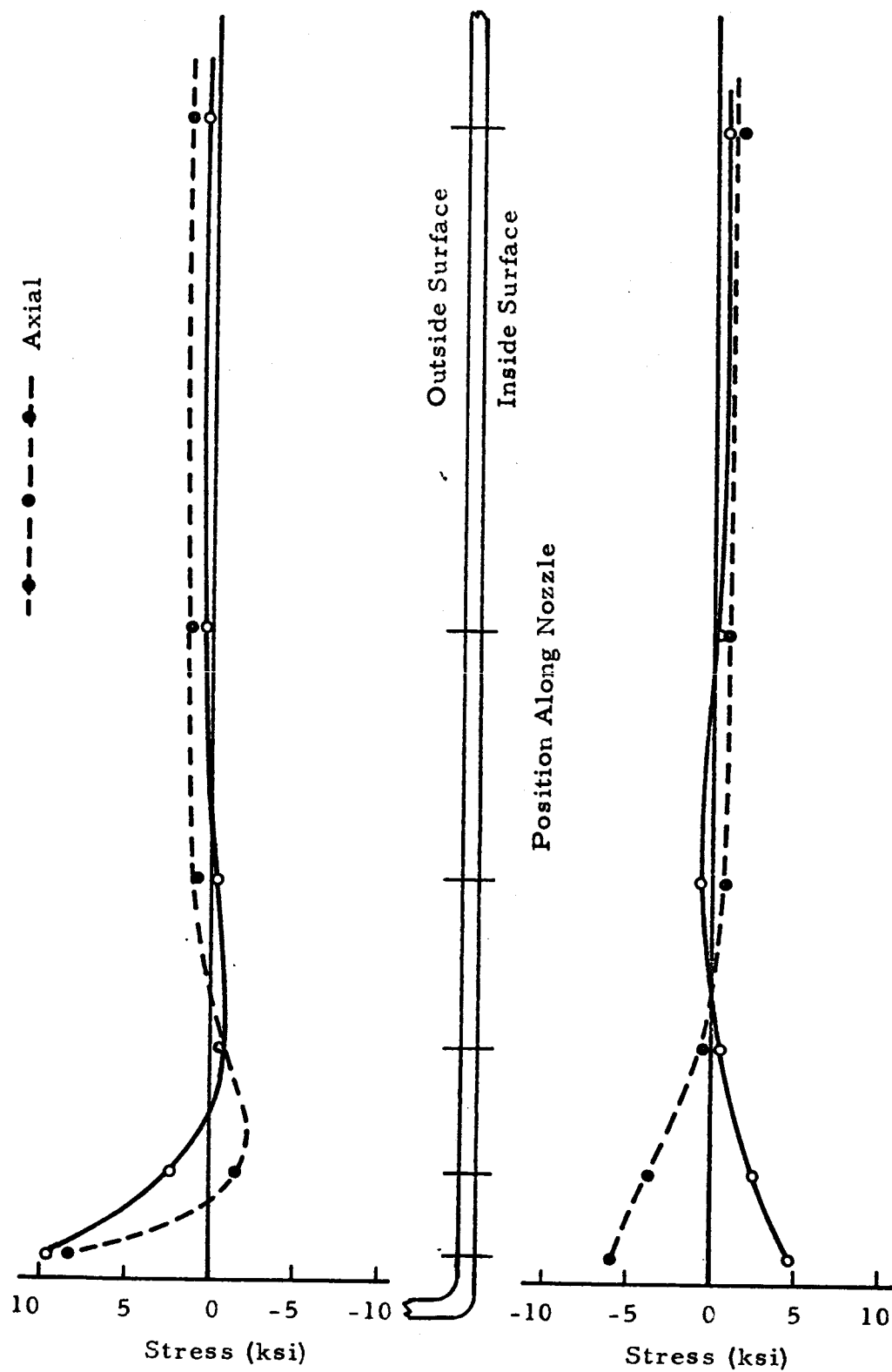


Fig. 26 STRESS DISTRIBUTION IN THE NOZZLE FOR A THRUST (OUTWARD) OF 6000 LB ON THE NOZZLE

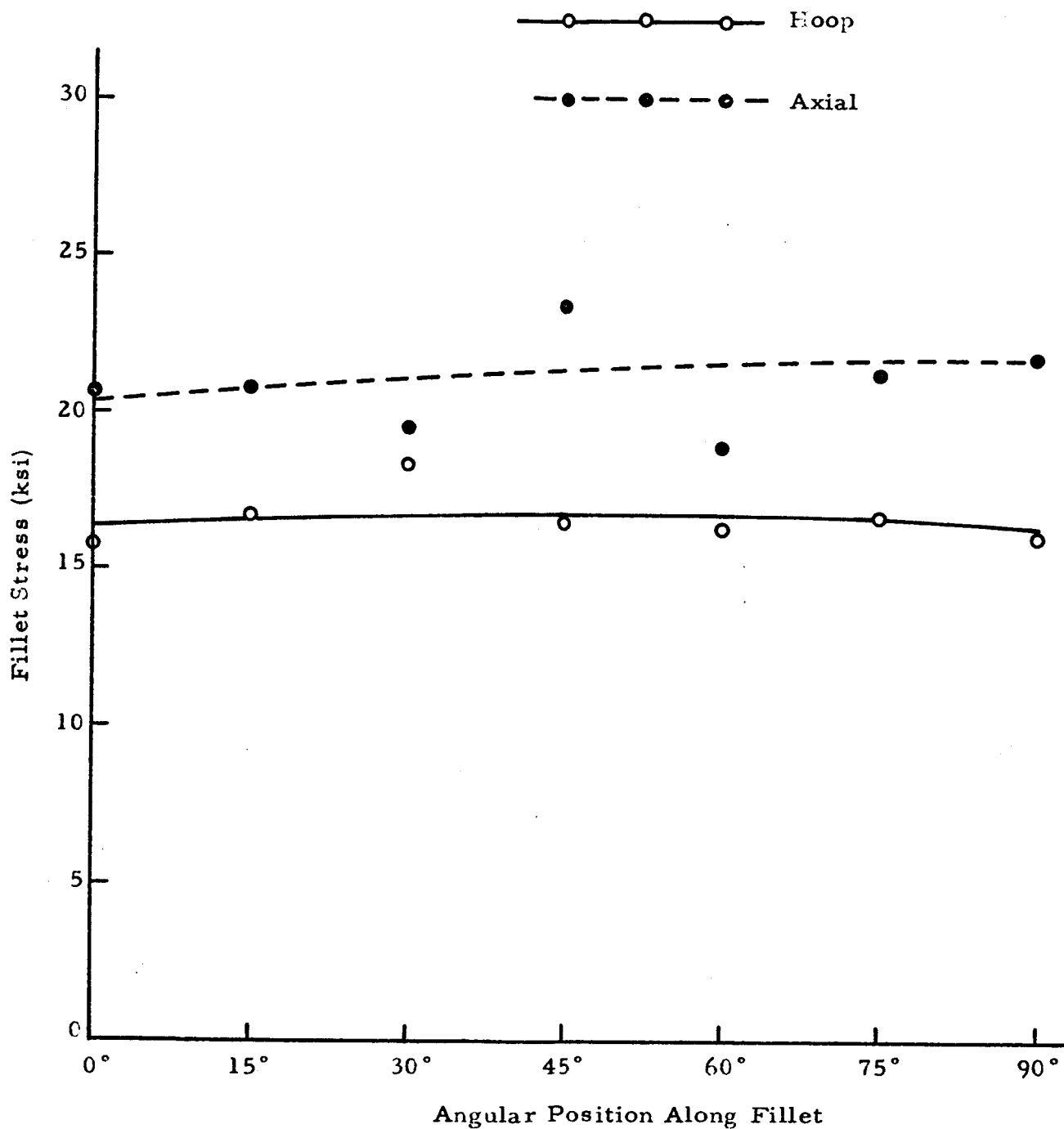


Fig. 27 STRESS DISTRIBUTION IN THE FILLET BETWEEN THE NOZZLE AND THE HEMISPHERE FOR A THRUST (OUTWARD) OF 6000 LB ON THE NOZZLE

Table 27

PRINCIPAL STRESSES IN VESSEL S-1 FOR A MOMENT (CLOCKWISE COUPLE)
OF 18000 IN-LB ON THE NOZZLE

Gage No.	Gage Location	PRIMARY LINE				SECONDARY LINE					
		Inside		Outside		Inside		Outside			
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
Lower											
1	Cylinder	+ 0.3	+ 0.1	+ 0.5	+ 0.1	- 0.2	- 0.1	- 0.4	- 0.1	- 0.1	- 0.1
2	Hemisphere	+ 0.6	- 0.5	+ 0.6	- 0.8	-	-	-	-	-	-
3	Hemisphere	+ 0.9	- 1.3	+ 0.9	- 1.5	- 0.6	+ 1.6	- 0.7	+ 1.3	+ 1.3	+ 1.3
4	Hemisphere	- 0.3	- 2.3	+ 3.0	- 1.7	-	-	-	-	-	-
5	Hemisphere	- 0.9	- 0.6	+ 4.4	- 0.3	+ 1.0	+ 0.6	- 4.0	+ 0.4	+ 0.4	+ 0.4
6	Hemisphere	+ 1.0	+ 4.2	+ 3.4	+ 2.8	-	-	-	-	-	-
7	Hemisphere	+11.6	+11.8	- 7.5	+ 3.3	-12.2	-10.9	+ 6.0	- 3.8	- 3.8	- 3.8
9	Nozzle	+10.3	+10.8	- 6.8	+ 5.0	-10.0	-11.1	+ 8.3	- 4.7	- 4.7	- 4.7
10	Nozzle	- 0.1	+ 3.8	+ 4.6	+ 3.5	-	-	-	-	-	-
11	Nozzle	- 0.4	- 0.3	+ 2.5	+ 0.7	+ 0.8	+ 0.7	- 2.8	- 0.6	- 0.6	- 0.6
12	Nozzle	+ 1.6	- 0.1	+ 0.9	- 0.3	-	-	-	-	-	-
13	Nozzle	+ 1.6	+ 0.3	+ 1.0	-	- 1.5	- 0.2	- 1.5	+ 0.3	+ 0.3	+ 0.3
14	Nozzle	+ 1.5	+ 0.1	+ 1.7	- 0.1	-	-	-	-	-	-

Table 28

**FILLET STRESSES IN VESSEL S-1 FOR A MOMENT
(CLOCKWISE COUPLE) OF 18000 IN-LB ON THE NOZZLE**

Gage No.	Gage Location	FILLET STRESS			
		Outside		Inside	
		Axial Stress (ksi)	Hoop Stress (ksi)	Axial Stress (ksi)	Hoop Stress (ksi)
8	0°	+22.0	+14.8	- 3.7	+ 6.5
23	15°	+23.5	+16.2	-	-
24	30°	+18.4	+12.5	-	-
25	45°	+14.9	+10.3	-	-
26	60°	+ 8.5	+ 6.9	-	-
27	75°	+ 3.8	+ 3.0	-	-
28	90°	+ 1.3	+ 1.0	-	-
19	180°	-20.4	-13.3	+ 4.4	- 7.0

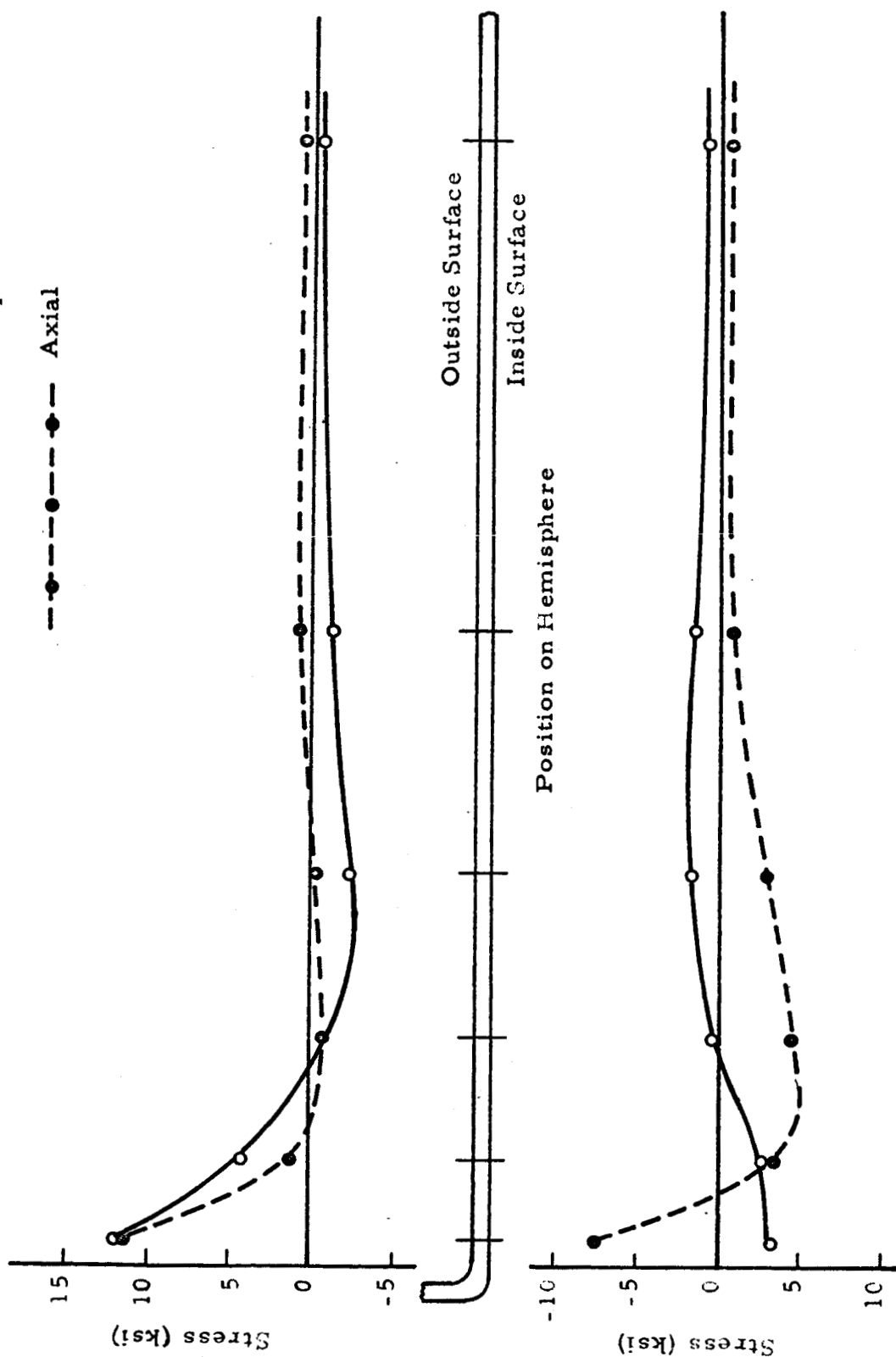


Fig. 28 STRESS DISTRIBUTION ON THE PLANE OF BENDING IN THE HEMISPHERE
FOR A MOMENT (CLOCKWISE COUPLE) OF 18000 IN.-LB ON THE NOZZLE

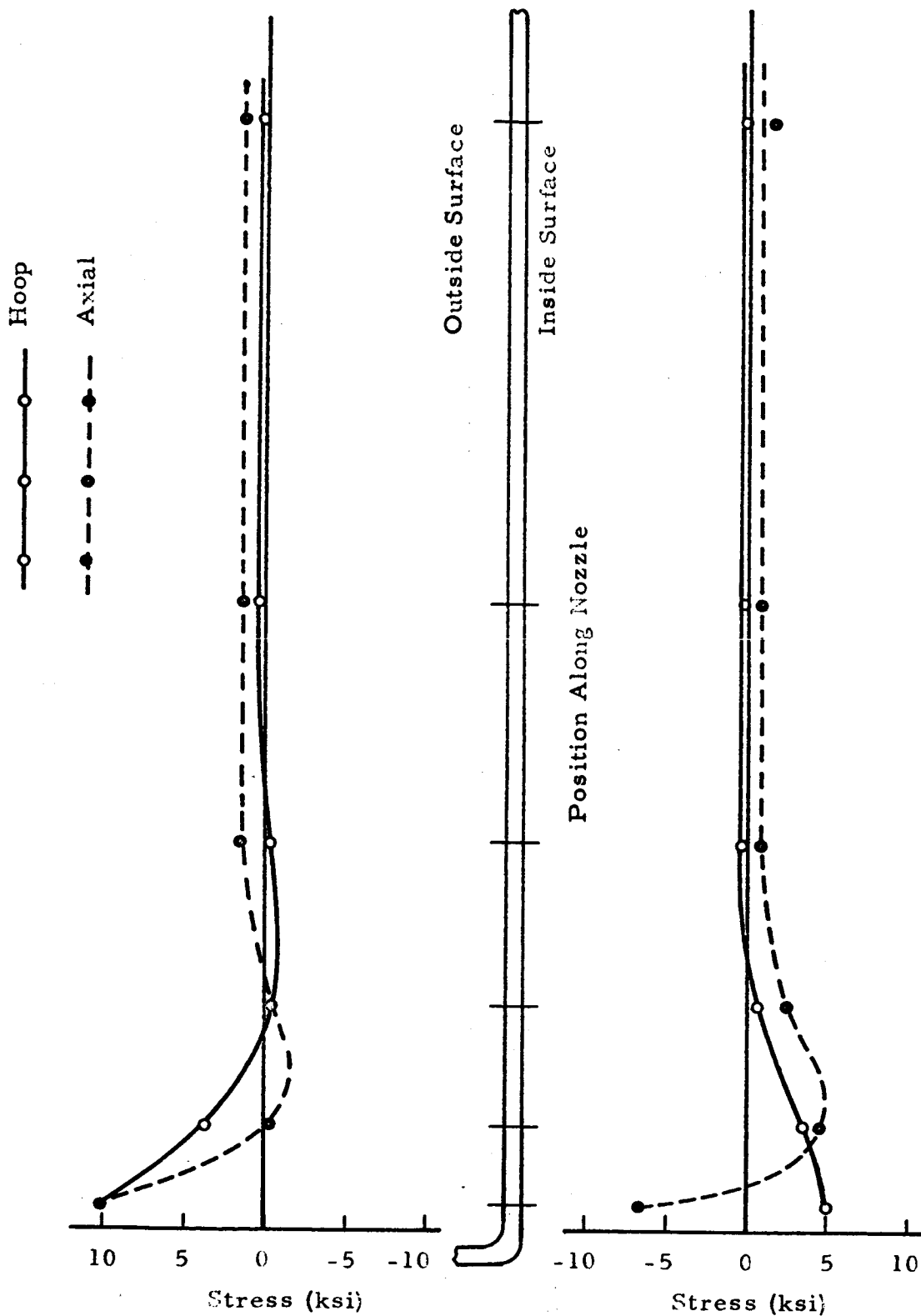


Fig. 29 STRESS DISTRIBUTION ON THE PLANE OF BENDING
IN THE NOZZLE FOR A MOMENT (CLOCKWISE COUPLE)
OF 18000 IN-LB ON THE NOZZLE

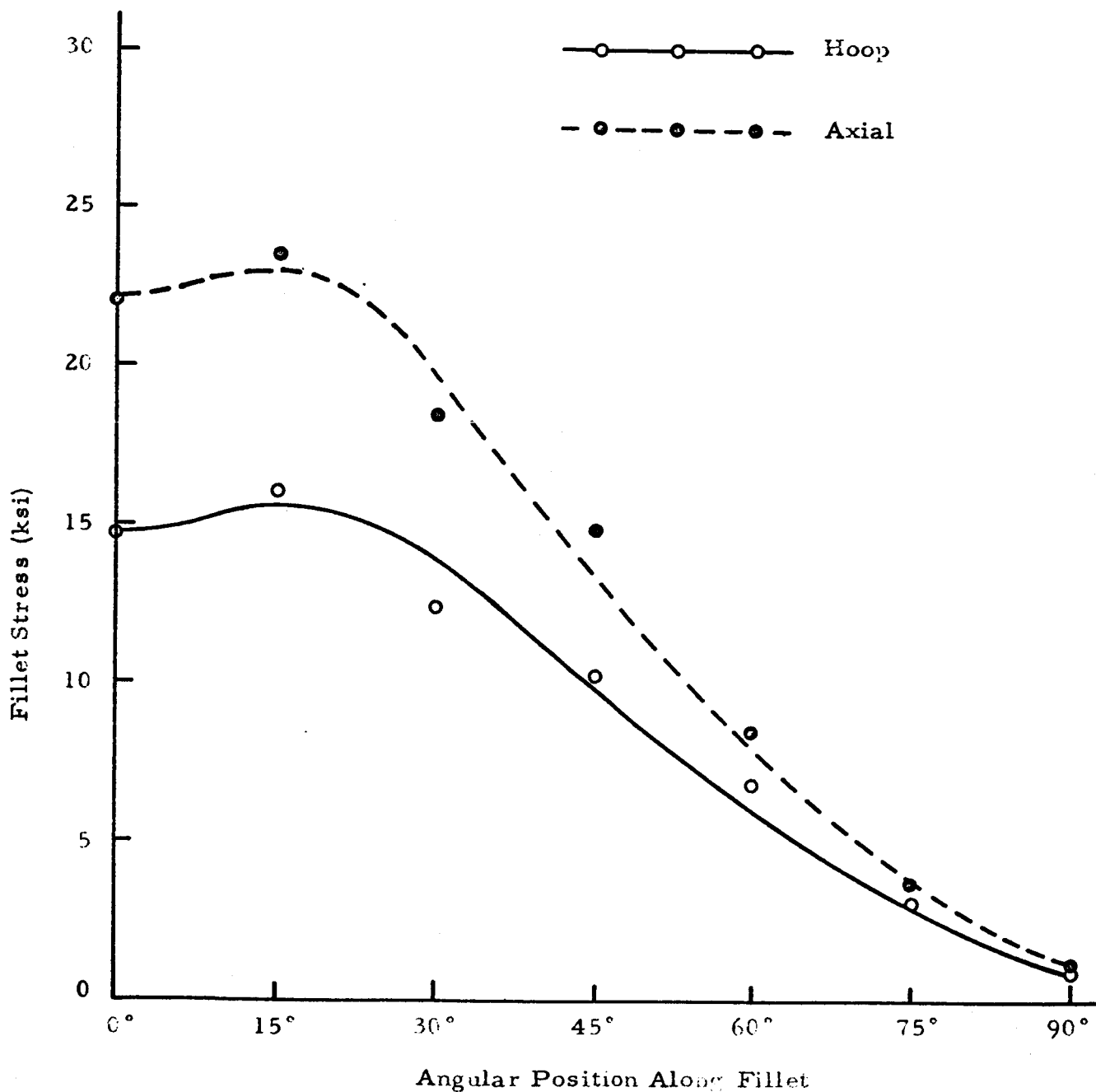


Fig. 30 STRESS DISTRIBUTION IN THE FILLET BETWEEN THE NOZZLE AND THE HEMISPHERE FOR A MOMENT (CLOCKWISE COUPLE) OF 18000 IN-LB ON THE NOZZLE